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# GAS FURNACES AND APPLIANCES

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APRIL 1988

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# WHY GAS?

If you already have a natural gas heating system and would like to get more out of it, or if you are considering replacing your furnace or other gas appliance, this book will help you with some key decisions. If you are thinking about switching to gas from some other fuel, it will help you estimate and compare relative fuel costs.

In 1980, roughly 68 percent of Montana residences were heated with natural gas or liquid propane. That's almost 193,000 homes. After gas, electricity was the next most popular heating source, heating about 15 percent of Montana homes. Montana is fortunate to have relatively low gas costs, with 1987 prices ranging from $3.36 to $4.81 per thousand cubic feet (mcf).

The amount you can save by switching to gas depends not only on the cost of your present fuel and installation costs, but also on your living patterns. Efficient operation of heating systems may allow homeowners with old leaky houses to spend less on fuel each month than their counterparts living in energy-efficient houses but operating their heating systems less efficiently. Without a doubt, it is important to understand how gas appliances may be operated efficiently.

Gas appliances can be a health hazard unless they are properly installed and maintained. Sheet metal contractors, heating and air conditioning installers, or Montana utility representatives can offer good advice on installing furnaces, water heaters, and other gas appliances. Many other excellent sources of information are listed at the end of this publication.

## Some Useful Definitions

Utility bills show that each type of energy is sold in different units — kilowatt-hours (kWh) for electricity, thousand cubic feet (mcf) for natural gas, or gallons for fuel oil. To compare the costs and heat production of various fuels, it is necessary to convert them to a common unit.

The common unit for comparing heat content is the **British thermal unit,** or **Btu**. It takes one Btu to raise one pound of water one degree Fahrenheit. Another rough approximation is that a wooden stick match produces about 1 Btu when burned. Heat produced by a furnace is usually expressed in thousands of Btus per hour, while annual energy requirements of a house will be expressed in millions. One kWh of electricity typically equals 3,412 Btu.

In Montana, natural gas contains about 930 Btu per cubic foot or 930,000 Btu per mcf. This value will vary depending on the source of the gas and the altitude where you live. A **therm** is another unit for measuring the heat content of natural gas. The Btu value of a therm does not change. One therm will always contain 100,000 Btu.

Heat pump capacities are rated in tons. Ice was once used to cool buildings and the amount of ice needed to cool a given area was reported in tons. One ton is equivalent to about 12,000 Btu/per hour.

Gas furnace efficiency, the ratio of energy output to input, can be measured in two ways. An older method measured efficiency while the furnace was running. This is known as **steady-state efficiency**. Using this method, older furnaces usually are found to be 50 to 70 percent efficient. In recent years, the American Gas Association and the National Bureau of Standards have developed a newer measure of overall furnace efficiency. The new method, called the **Annual Fuel Utilization Efficiency (AFUE)** rating, also takes into consideration the energy requirements of blowers and the energy used during start-up, cool down, and between heating cycles. The AFUE rating more accurately reflects the true efficiency of a furnace. Although the rating does not look at the efficiency of ductwork or add-on devices, it does provide a way to compare the efficiency of newer furnaces. Prospective purchasers should ask their dealer for these ratings. The dealer is required to make the AFUE ratings available to the customer. The Gas Appliance Manufacturers Association also publishes a directory that lists the AFUE ratings (see references at the end of this publication).

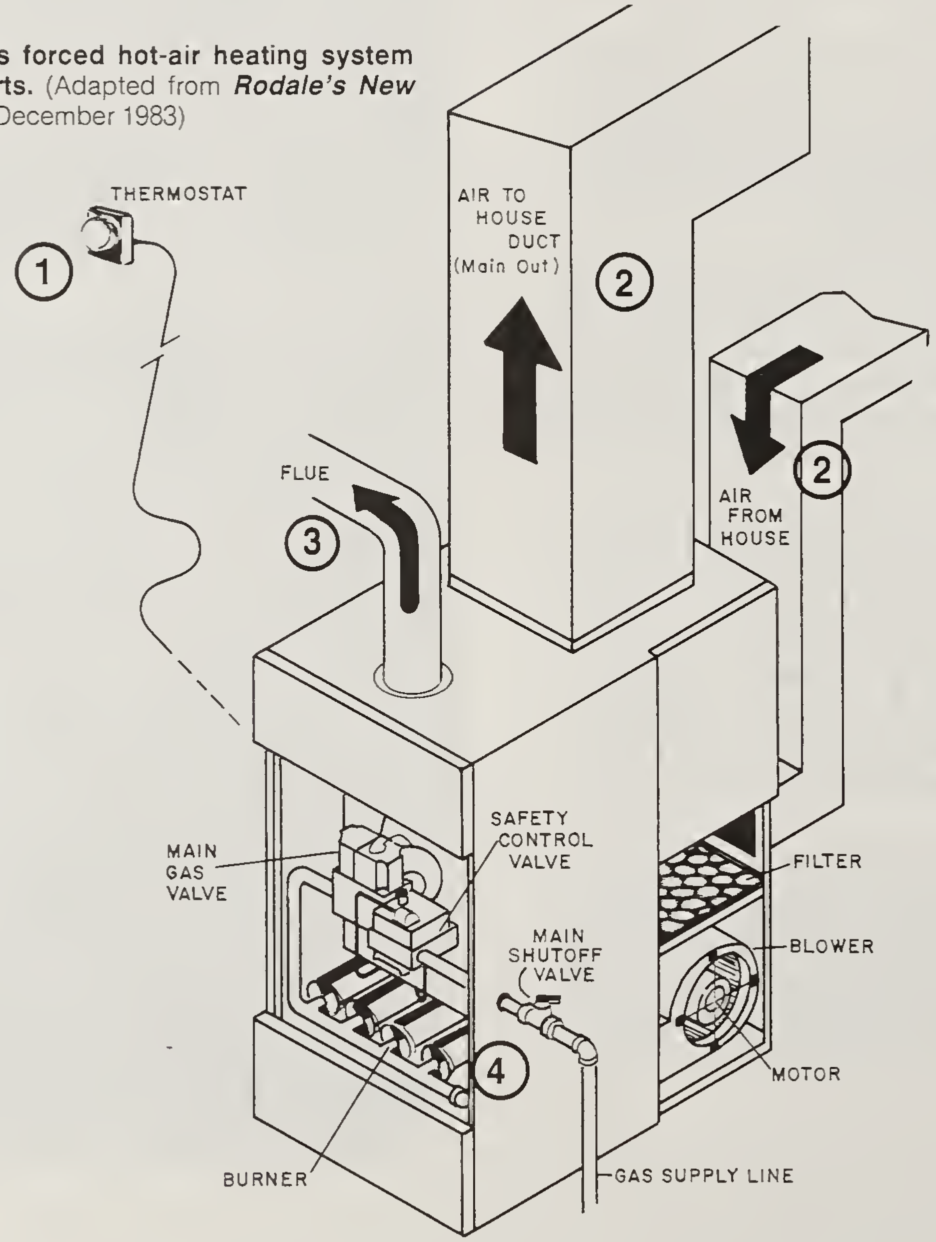
## Before You Replace Your Furnace

If you're thinking of replacing a furnace to save money on your fuel bills, you should first consider conservation measures that may be more cost effective. The following measures are estimated to pay for themselves in 7 years or less.

1. An energy audit. In an energy audit, a trained technician from a local utility examines your house to determine how it can be made more energy efficient. Many Montana utilities offer energy audits free of charge.
2. Caulk and weatherstrip to reduce drafts and leakage of air into and out of the house.
3. Weatherstrip doors between heated spaces and unheated basements or attics.
4. Insulate attics, ceilings, floors, and crawl spaces.
5. If you currently have single-pane windows, install plastic, wood, or aluminum storm windows to reduce drafts and heat loss through glass.
6. Lower thermostat settings. Each degree that you lower your thermostat setting below 72 degrees can result in a 3 percent fuel savings. Small children, the elderly, or those who are ill may need the 72 degree temperature setting.
7. Clean your furnace and ductwork. To check your furnace filter, hold it up to the light. If little or no light can pass through, replace or clean the filter. Filters should be checked several times each heating season.
8. Have a heating contractor check your furnace every 2-3 years to be sure it is in proper running order with the flame burning properly.

These measures and many others are discussed more thoroughly in The Montana Energy Book — Proven Ways to Save Money In and Around Your Home and in Twelve Ways to Turn Down Your Energy Bills. Both these books are available free of charge from the Montana DNRC and from the Energy Information Centers around the state. For the location of your nearest Energy Information Center, contact your Local Cooperative Extension Office.

**A conventional gas forced hot-air heating system has four major parts.** (Adapted from ***Rodale's New Shelter,*** November/December 1983)



# FURNACES AND HEATING SYSTEMS

## How Conventional Heating Systems Work

A heating system using natural gas or propane has four major parts. The thermostat **(1)** controls operation of a system. When the house temperature drops below a selected point, the thermostat activates the burner. The distribution equipment **(2)** consists of the piping or ductwork that carries the hot water, steam, or hot air through your house. The chimney or flue **(3)** exhausts smoke and gases from the boiler or furnace. The boiler or furnace **(4)** consists of three main parts — the burner, the combustion chamber, and the heat exchanger. See diagram on page 6.

In a natural gas or propane system, the burner consists of a series of tubes with small holes (orifices) much like the burners on a gas range. The burner is located in the combustion chamber. Heat generated by the burner is applied to the heat exchanger where it is transferred to air ducts or water pipes for circulation throughout the house. When burners have raised the temperature of air or water in the heat exchanger, a fan or water pump circulates the hot air or water through ducts or radiators around your home. In older gravity hot-air heating systems, fans do not force the air out of the furnace. Rather, the buoyant warm air moves through ductwork by itself.

### Money Up the Chimney

If your gas furnace is 10 or more years old, it typically operates within an efficiency range of 50 to 65 percent. This means that for every $100 paid for home heating, you receive $50 to $65 worth of heat. Where does the waste go in these older furnaces?

About half of the energy lost from a conventional furnace escapes with the hot combustion gases that go up the chimney as the furnace operates. Exhaust gases typically are heated to 450-500 degrees F. so they will be buoyant enough to safely exit the chimney. Water vapor formed during combustion also goes up the chimney.

The other half of energy losses from conventional furnaces occurs when the furnace is not circulating hot air through your home. One source of these losses is the heat-up and cool-down of the combustion chamber and heat exchanger at the beginning and end of the operating cycle. When the furnace cools down to a set point and the blower motor turns off, heat is not transferred to the rest of your house and is lost up the chimney. The amount of heat lost this way will be directly proportional to the number of on/off cycles a furnace goes through in a heating season. Furnaces that are too large (oversized) for a house go through more on/off cycles than those that are properly sized, and so lose more energy and cost more to operate.

Air infiltration is another source of heat loss. If your furnace uses household air for combustion, cooler outside air will be drawn in to replace it. As outside air is drawn in, it cools your house and increases heating demand. Warm inside air also is lost up the chimney even when the furnace is not running.

A third contributor to losses is a continuously burning pilot light. Heat produced by the pilot light when the furnace is not running will be lost up the chimney. The draft created by the pilot light will also draw some indoor air up the chimney.

Heating system losses that are not directly related to furnace operation can also contribute to inefficiency. Leaky, uninsulated ductwork in unheated spaces or open heating vents to unused rooms can contribute to system losses. Large system losses are common with long ducts through unheated attics or crawl spaces.

## High-Efficiency Heating Systems: How They Work

Will you be satisfied with the performance of a new high-efficiency gas furnace? Judging from comments of homeowners who have installed them, you probably will.

Ralph and Marjorie Berg of Great Falls replaced their 37-year old Mueller gravity heating system with a new Carrier 94-percent-efficient gas furnace. New ductwork was also installed for the change to a forced-air heating system. "We notice the more even heat," Ralph said. "We get heat from vents on the outside perimeter of the house now, the reverse of what it was before with vents on the inside walls. The system heats the farthest corners of the house, and is much more efficient and comfortable."

Ed and Nancy Noble selected the largest high-efficiency gas furnace they could find for their new superinsulated 7,000-square foot house in Great Falls. Their 122,000-Btu Payne furnace "does a tremendous job" of heating their home. "We were very satisfied with the 86-percent-efficient furnace we had in our previous home," Ed said, "but we've noticed the quietness and improved damper control with the newer 97-percent-efficient furnace we now have." Monthly gas bills for operation of the furnace and two Bradford-White gas water heaters have not exceeded $60. Two fireplaces provide supplemental heat.

The new heating systems available today have efficiencies from 80 percent to the high 90s. What makes the newer models so much more efficient? Typically, those furnaces combine some of the following devices to reduce losses:

1. An **intermittent ignition** or **electronic ignition** that replaces a standing pilot light and supplies an ignition spark only as needed.
2. A **secondary heat exchanger.** In addition to the primary heat exchanger in conventional gas furnaces, new gas furnaces with efficiencies above 80 percent will have a second (and sometimes a third) heat exchanger through which combustion gases pass. These additional heat exchangers draw off heat, condensing water vapor and reducing the temperature of exiting gases from 350-450 degrees F. to approximately 100—130 degrees F.
3. An **auxiliary fan system** for stabilizing air movement through the combustion chamber and exhausting flue gases. Conventional furnaces rely on natural chimney draft to draw air through the furnace for combustion and exhaust. Newer furnaces use one of three types of auxiliary fan systems to move air. A forced-draft system uses a fan to push air into the combustion chamber. Induced draft systems pull air through the combustion chamber and force exhaust gases out the flue. Both these systems use indoor air for combustion. A third type of system uses "sealed combustion," in which direct vent fans draw outside air in for combustion and exhaust flue gases back outdoors. Indoor air is not used in the sealed combustion process and the furnace's combustion chamber is sealed off from the rest of the house.

Table 1 summarizes the types, outputs, efficiencies, and costs of high-efficiency heating systems now available.

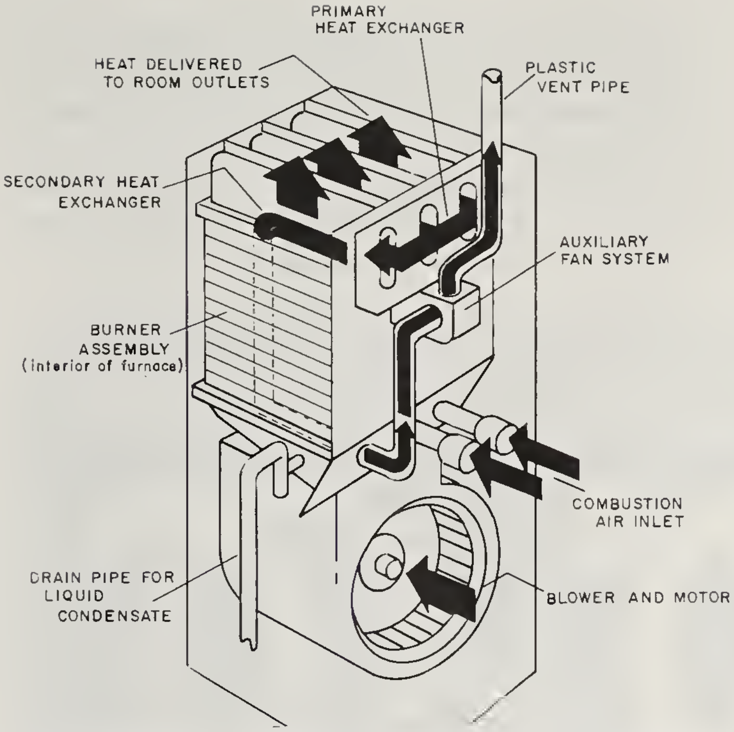
**Table 1. High-Efficiency Gas Heating Systems***

| Type | Output (Btu/hour) | AFUE (percent efficiency) | Estimated installed cost |
|---|---|---|---|
| Condensing | 30,000 - 130,000 | 85 - 97 | $1200 - $2200 |
| Pulse | 40,000 - 97,000 | 93 - 97 | $2000 - $3000 |
| Hydronic | 33,000 - 100,000 | 84 - 87 | $1500 - $3500 |
| Heat Pipe | 63,000 - 90,000 | 85 | $1200 - $1400 |
| Space Heaters | 12,000 - 50,000 | 70 - 75 | $ 250 - $ 600 |

* All numbers cover a wide range of model types and sizes for high-efficiency furnaces and space heaters. Installation costs do not include installing ductwork throughout a house.

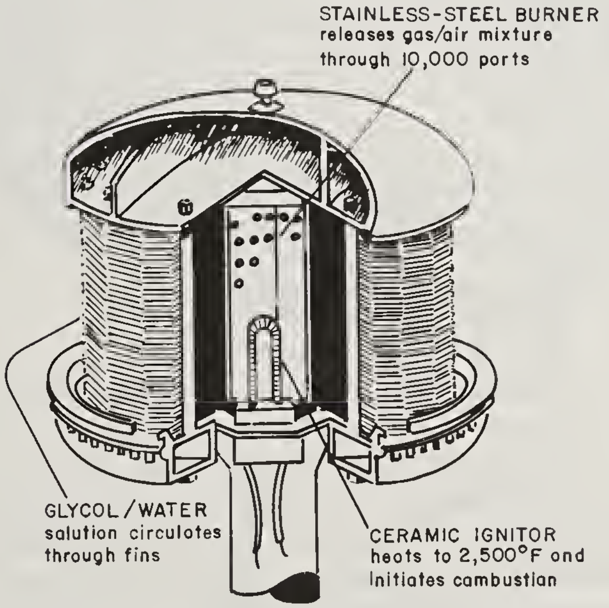
## Condensing or Recuperative Furnaces

Condensing and recuperative furnaces capture additional heat with a second heat exchanger, and sometimes a third. Hot exhaust gases and water vapor that normally escape up the chimney are cooled enough so that condensation occurs — typically to around 100-130 degrees F. Heat captured by the secondary heat exchanger during the condensation process is then circulated to the house. Cooled exhaust gases can be vented up a chimney or sometimes through a PVC pipe through an outside wall. The slightly acidic liquid condensate from the furnace is collected and piped to a drain.



**High-efficiency condensing furnaces: how they work.** (Adapted from ***Consumer Reports,*** January 1987)

A second design for condensing furnaces combines the functions of burner, combustion chamber, and heat exchanger into a "heat transfer module." A gas/air mixture is introduced into the stainless steel combustion chamber of the module where an electrically-powered ceramic igniter, heated to 2500 degrees F., ignites the mixture. A mixture of glycol and water circulating around the combustion chamber absorbs the heat and is pumped to the primary heat exchanger. The forced-air heating system transfers heat from the heat exchanger to the rest of the house.


STAINLESS-STEEL BURNER releases gas/air mixture through 10,000 ports
GLYCOL/WATER solution circulates through fins
CERAMIC IGNITOR heats to 2,500°F and initiates combustion

**The heat transfer module in some models of condensing furnaces combines the functions of burner, combustion chamber, and heat exchanger.** (Adapted from ***Popular Mechanics,*** September 1983)

### Early Problems

Some early problems with condensing furnaces were caused by improper venting or corrosive chemicals in combustion air. In one instance, the vent on an 80-percent-efficient boiler installed in a house in Lewistown caused condensation problems, according to Gary Willis, District Marketing Supervisor for the Montana Power Company. The exhaust vent was not extended far enough from the outside wall, which caused moisture build-up on exterior walls under the eaves. "During cold weather, icicles kept building up and up on the side of the house," Gary said, and suggested that this problem can be avoided by extending the vent farther from the house or by running a PVC pipe up a chimney if flue and vent sizes allow.

The condensed water vapor produced by a secondary heat exchanger contains trace elements from fuel and combustion air. When indoor air is used for combustion, traces of chlorine from laundry bleach and cleaning products may be present in the condensate. Other corrosive chemicals enter the combustion process in condensing furnaces that operate in beauty shops or veterinarian clinics. The resulting condensate is corrosive and slightly acidic, similar to carbonated soft drinks. In early condensing furnaces, heat exchangers and metal flue pipes sometimes corroded. Unlined masonry chimneys are also susceptible to corrosion.

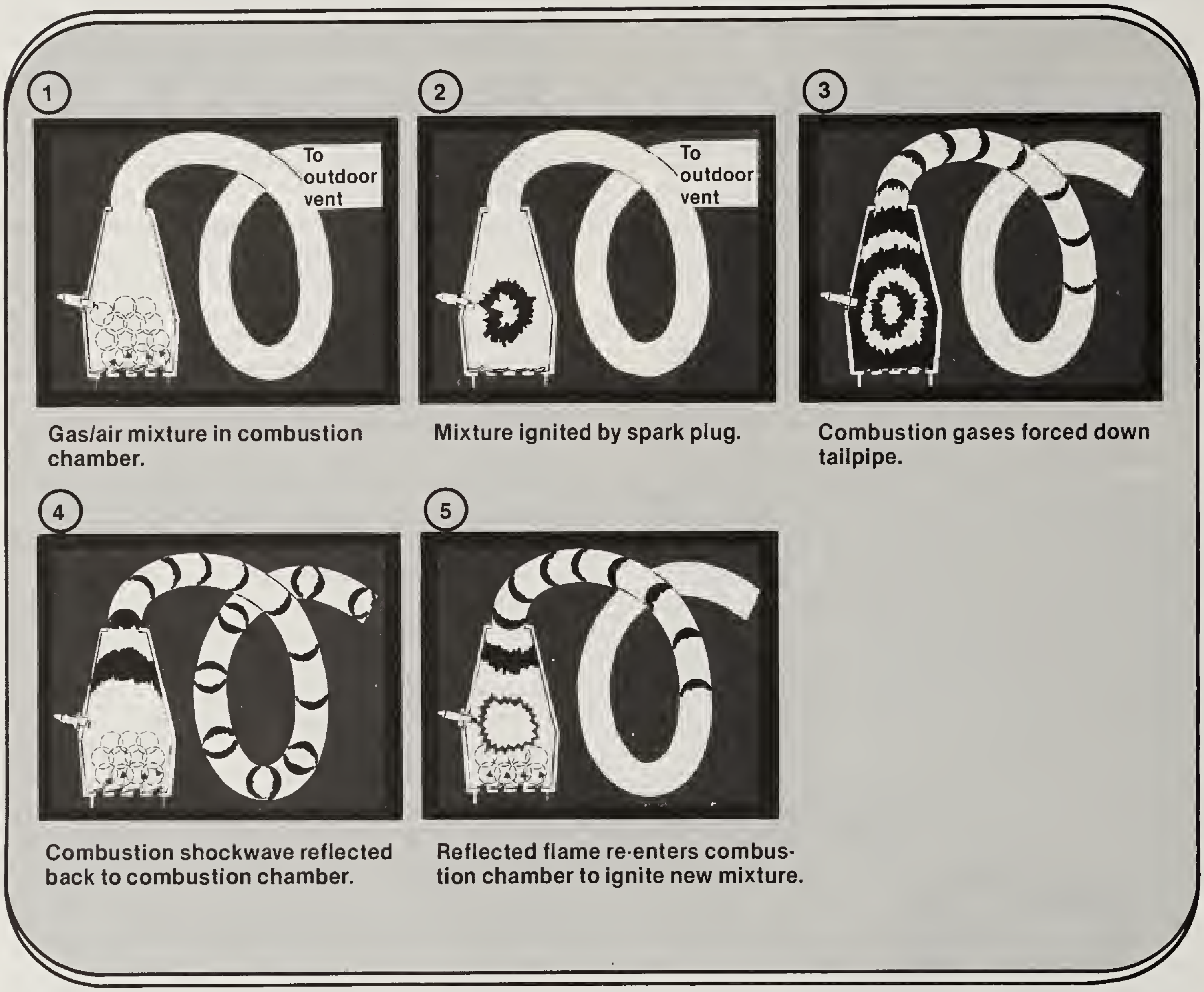
To avoid these problems, modern condensing furnaces have heat exchangers constructed of stainless steel or other materials treated to resist corrosion. Condensate is collected inside the furnace and piped to a drain. If combustion gases are vented up a masonry chimney, a stainless steel liner or heat resistant plastic pipe can be inserted to prevent corrosion of the chimney. Outside air can be brought in for combustion, rather than using indoor air. Some new furnaces can be vented through a side wall with small-diameter plastic pipe, where permitted by local codes. If you are purchasing a condensing furnace, check with a heating contractor regarding appropriate installation and venting.

## Pulse Combustion Furnaces

Pulse combustion furnaces are another type of condensing furnace with a different combustion process. A single spark begins the combustion sequence, which consists of repeated pulses (small explosions). The process begins when small amounts of fuel and air are blown into the combustion chamber through valves **(1)**. This mixture is ignited by a spark plug **(2)**, causing the first pulse or explosion, which closes the valves and forces the combustion products down the tail pipe **(3)**. The pipe has a specific length so that the shock wave from the pulse reaches the end and is reflected back to the combustion chamber **(4)**.

As the combustion products from the first pulse are forced out the tail pipe, a slight negative pressure is created in the combustion chamber. The pressure reduction in the chamber allows the valves to open again, admitting more gas and air. When the reflected wave re-enters the chamber **(4)**, there is enough flame in it to ignite the new air/gas mixture, causing the second pulse which continues the process **(5)**. Once combustion is started, it becomes self-perpetuating. Combustion occurs 60 to 70 times a second.

In early models, the rapid, turbulent combustion process of pulse furnaces produced unwanted noise and vibration. In current models, this vibration noise is reduced with pads under the furnace cabinet, foam insulation for the supports of the vent and intake tubing, flexible canvas boots and mufflers on intake and exhaust tubing, and a flexible gas line connector. These techniques significantly reduce noise.



**Gas/air mixture in combustion chamber.**

**Mixture ignited by spark plug.**

**Combustion gases forced down tailpipe.**

**Combustion shockwave reflected back to combustion chamber.**

**Reflected flame re-enters combustion chamber to ignite new mixture.**

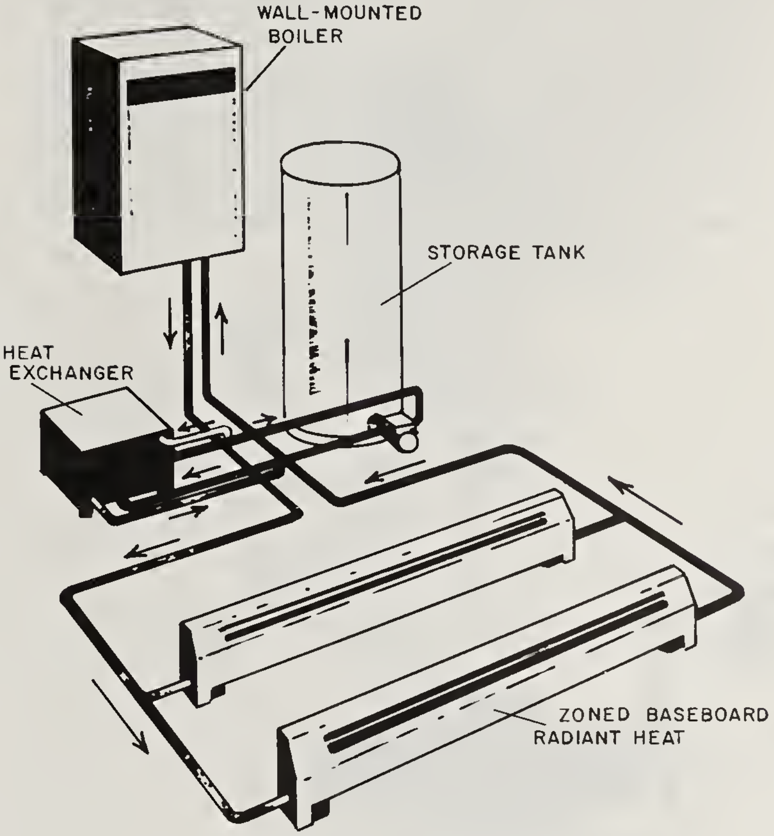
**The pulse combustion process.** (Adapted from ***The Montana Energy Book,*** 1986)

## Integrated Hydronic Heating Systems

In general, the term "hydronic" applies to any heating system that uses circulating hot water through some part of the system. Perhaps the most familiar hydronic heating system is the gas- or oil-fired boiler with either a hot water or steam distribution system such as radiators. This system permits more precise room-to-room temperature control than forced-air systems by establishing several closed loops or zones of circulating hot water that can be individually controlled with thermostats and valves. It supplies radiant heat and lacks the warm moving air of forced-air heating systems.

Increasing interest in energy efficiency and trends toward more tightly built and better insulated housing have resulted in the development of "integrated" systems, which combine space heating with domestic water heating and sometimes with ventilation functions. These integrated hydronic systems typically use one source of hot water for both space heating and domestic hot water needs. The following sections describe a few of these new systems.

One new hydronic heating system uses a small-capacity, wall-mounted boiler, integrating space heating with domestic hot water needs. An external heat exchanger uses hot water supplied by the boiler to heat household water. These units are suitable for tightly-built homes, apartments, or townhouses with low heating demand.

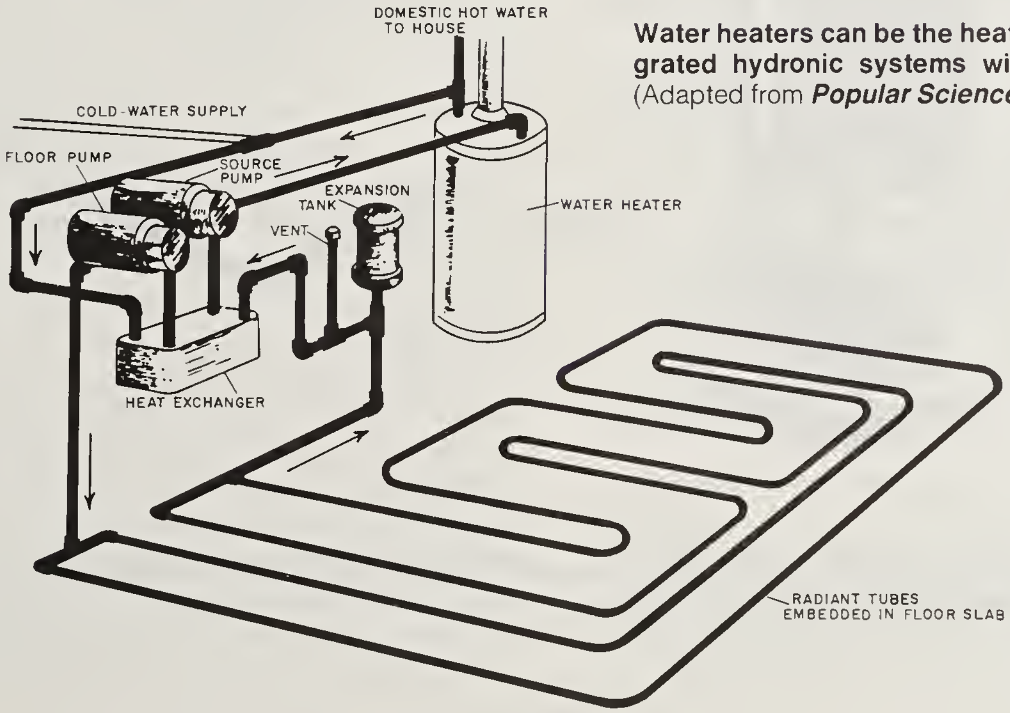


**A hydronic heating system with a wall-mounted boiler integrates space heating with domestic hot water needs.** (Adapted from ***Energy Design Update,*** August 1985)

Another variation uses a free-standing storage tank for boiler-heated water. The tank stores water for household space heating at 170 degrees F. Domestic hot water is heated by running it through a coil within the boiler storage tank. A mixing valve blends cold water with the water exiting the coil to prevent contact with very hot water at the hot water faucet.

The two previously mentioned systems have small-capacity boilers as the heat source, with heat exchangers integrated into the system for heating domestic hot water. Outputs range from 33,000 to 65,000 Btu/hour. Efficiencies average 85 percent. They have the advantage of avoiding the need for more than one combustion unit per house. Space demands are reduced and energy bills should be lower.

In some integrated hydronic systems, high-efficiency, high-capacity water heaters are used in place of boilers to meet domestic hot water and space heating needs. One type of integrated system circulates water and exchanges heat between two closed loops — one for domestic hot water and the other for heating pipes buried in a floor slab or for wall-mounted baseboards. When space heat is needed, hot water from the water heater circulates through a heat exchanger. As heat is transferred from the domestic water loop to the space heating loop, pumps circulate the space heat water through polybutylene tubes embedded in the floor or to baseboard radiators, supplying radiant heat to the house.

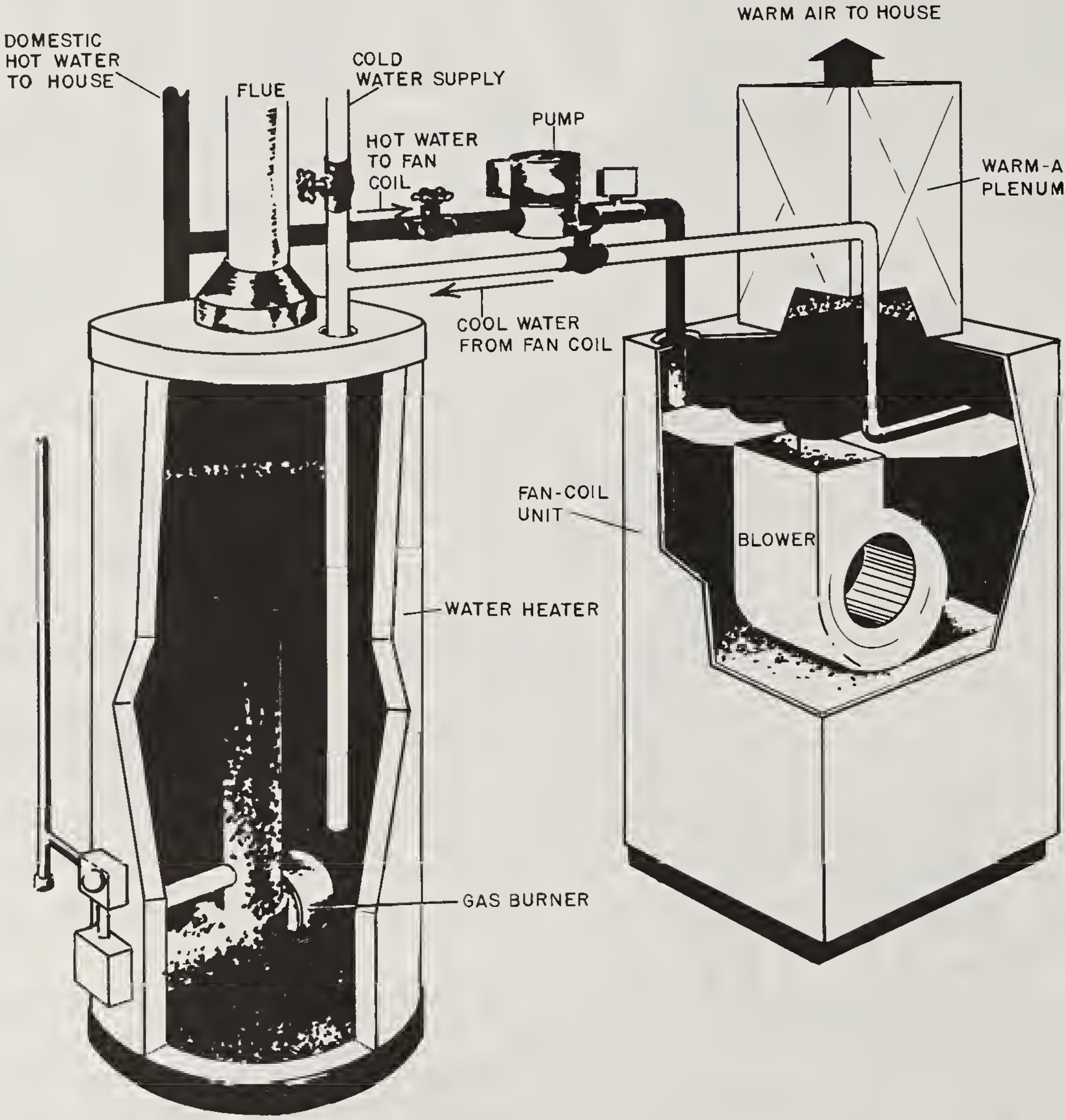


**Water heaters can be the heat source for some integrated hydronic systems with radiant floor heat.** (Adapted from ***Popular Science,*** October 1986)

A "fan coil" system is another type of integrated system that uses a water heater as the heat source, but provides warm air for space heating rather than radiant heat from circulating water. When the thermostat signals for more heat, a pump circulates hot water from the water heater to a heat exchanger in the fan coil. As the water circulates, a blower moves air past the heat exchanger, picking up heat for circulation to the house much the same as a forced-air furnace.

Using a water heater for space heating means that it will run more. Increased efficiency and durability are important features to look for if you plan to use a water heater this way, since conventional water heaters waste approximately 50 percent of their heat over the course of a year. High-efficiency water heaters decrease these losses with energy-efficient features, such as a combustion chamber within the tank for reducing heat loss to the surrounding air. See the section on water heaters later in this book for more on energy-efficient features.

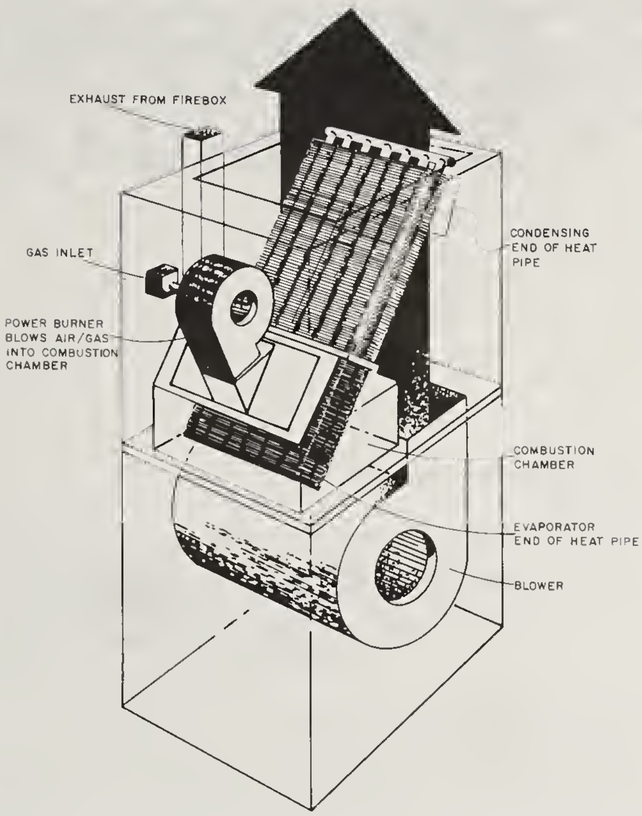
As new houses are built more tightly and with more insulation, the trend toward integrated heating, cooling, water heating, and ventilation systems is likely to continue. Integrated systems may meet heating and domestic hot water needs more efficiently than independently functioning systems. Savings can result from eliminating a furnace and pilot light. With new construction, it may also be possible to eliminate a chimney. Space demands are reduced by integrating functions and appliances.



**A water heater and fan-coil unit are another type of integrated heating system.** (Adapted from ***Popular Science,*** October 1986)

## Heat Pipe Furnaces

The heat pipe furnace is another new type of high-efficiency gas furnace. Unlike the others described earlier, it is not a condensing furnace. Its high efficiency (around 85 percent AFUE) and name are derived from the heat pipe mechanism that makes it work.


EXHAUST FROM FIREBOX
GAS INLET
POWER BURNER BLOWS AIR/GAS INTO COMBUSTION CHAMBER
CONDENSING END OF HEAT PIPE
COMBUSTION CHAMBER
EVAPORATOR END OF HEAT PIPE
BLOWER

**The heat pipe furnace.** (Adapted from ***Mechanix Illustrated,*** November 1983)

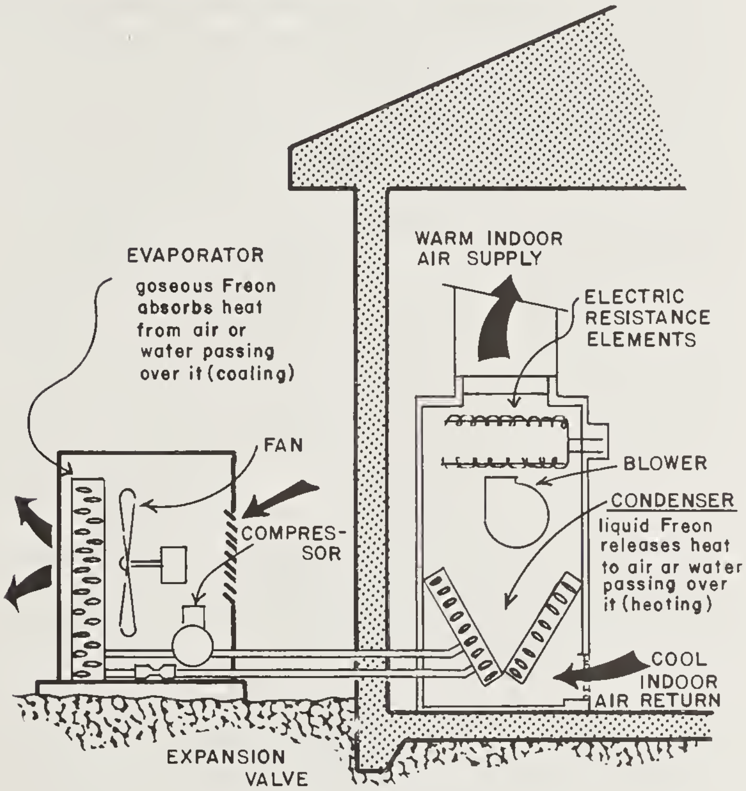
A heat pipe is an enclosed tube containing fluid. Heat pipe furnaces contain a series of these tubes for the transfer of heat. The lower ends of the pipes are located in the combustion chamber of the furnace. As the fluid is heated to the boiling point, it evaporates and rises within the tubes. At the upper end of the tubes, a stream of air from the furnace blower cools and condenses the vapor, releasing heat to the circulating air. Following condensation, the fluid returns to the bottom of the tube to be reheated and continue the process.

The heat-pipe furnace has several of the same energy-efficient features used in other condensing furnaces. These include an intermittent igniter rather than a standing pilot light, a blower for premixing gas and air, and the option of venting low temperature exhaust gases through a side wall. The heat contained in combustion gases is not captured in a secondary heat exchanger in these furnaces. Consequently, condensation does not occur within the combustion chamber. These furnaces require a corrosion-resistant vent or flue since some condensation of combustion gases can occur here. A small diameter condensate drain is also necessary to drain off this liquid.

## Gas Heat Pumps — Expected in the Future

An air-based heat pump is a highly efficient heat exchanger that removes heat from outside air and transfers it into the house. Heat pumps also can provide cooling. In simple terms, heat pumps work like freezers or refrigerators in reverse. Tubing containing Freon absorbs any heat within a freezer and transfers it to coils on the outside of the freezer. Then the heat is transferred to the surrounding air. You may have felt this warm air coming from the back or bottom of your refrigerator or freezer.

Currently, most heat pumps are electrically powered, but the first gas-fired heat pumps for household use should start showing up in the market place in the next 2 to 5 years. A gas-fired heat pump will probably have a compressor powered by natural gas. Except for fuel, the operation of gas and electric heat pumps is similar. In general, air-based heat pumps probably will not work well in Montana's cold climate. For more information on heat pumps, see the DNRC publication Using the Earth to Heat and Cool Homes.


EVAPORATOR
goseous Freon absorbs heat from air or water passing over it (cooling)
FAN
COMPRESSOR
EXPANSION VALVE
WARM INDOOR AIR SUPPLY
ELECTRIC RESISTANCE ELEMENTS
BLOWER
CONDENSER
liquid Freon releases heat to air or water passing over it (heating)
COOL INDOOR AIR RETURN

**An air-based heat pump will remove heat from outside air and transfer it into the house.** (Adapted from ***Home Energy,*** 1984 and ***Mechanical Systems Retrofit Manual,*** 1987)

## Gas Space Heaters

Several wall-mounted gas space heaters are available on the market. These units are suitable for heating small areas where a portable kerosene or electric heater might otherwise be used. They work well for basements, workshop additions, or homes with small heating requirements. As with full-sized furnaces, there are a number of design variations.

Some of these heaters draw combustion air from within the house and others take combustion air through a duct from outside. Heaters drawing air from outside the house are most often mounted directly on an outside wall with combustion fumes vented through the wall. Other heaters connect to a chimney flue. An older design vents combustion fumes into the house creating potential carbon monoxide problems. According to the Uniform Mechanical Code, unvented fuel-burning room heaters shall not be installed, used, or maintained in any hotel, apartment, or dwelling.

A new type of space heater uses pulsed combustion rather than conventional gas burners. These pulsed combustion heaters are sealed systems that draw combustion air directly from the outdoors and vent combustion gases directly outside. They are among the most efficient space heaters available.

Natural gas heaters are not as portable as kerosene or electric heaters, but they eliminate the messy job of filling a fuel tank on a kerosene stove. Gas wall heaters cost about $250 to $600 to purchase and install depending on their capacity and additional features.

# INSTALLING A FURNACE

## Furnace Installation in New Homes

If you are building a new home, consider heating system design and installation before your house plans are completed. Your architect should calculate heat loss from the house to determine the size of furnace. You can also talk with a heating contractor to determine what size furnace the house needs and to make sure that there is enough room for installing the heating system. Servicemen and contractors suggest you provide adequate headroom around the furnace. If you are installing a condensing furnace, make sure there is a floor drain for condensate near the furnace. It's also a good idea to check whether the design configuration (direction of airflow) of the furnace matches the proposed installation.

Dick and Irene Bottomly of Sun River, Montana, discovered they should have paid more attention to the operating principles of their high-efficiency Amana gas furnace when building their new home. "We designed a closet in the garage for it, then found the furnace had the heat discharge through its top," Dick said. "We had to dig a 5-foot x 12-foot x 8-foot hole beneath the sunroom and put concrete in the bottom to hold the furnace. For the time and effort, we could have put in a small basement."

If you plan to build an energy-efficient home, be wary of the contractor or builder who determines furnace size based on old rules of thumb, such as the idea that a certain size furnace is needed to match a given square footage. Many houses have furnaces much larger than necessary. Small furnaces cost less to purchase and operate than large furnaces, and are more efficient when correctly sized for heating demand.

Ted and Clara Becker had a big job convincing a heating contractor that one gas furnace would be enough for their new 4,300-square foot home in Bozeman. "We've found the electric baseboard heaters installed in the downstairs rooms for supplemental heat aren't needed," Ted commented. "The gas furnace could have heated the whole downstairs too. Manufacturers of heating equipment have specifications that aren't scaled for energy-efficient houses. Their tables said we should have a furnace rated at more than 100,000 Btu per hour."

"One contractor wanted to put in two 60,000 Btu furnaces, one downstairs and one upstairs. That would have been very expensive. Another contractor agreed to put in one 100,000 Btu, 94-percent-efficient gas furnace to serve the main floor and two rooms downstairs, with electric baseboard in the other rooms. Even when it's cold and the wind is blowing, the furnace is just loafing — running for 5 minutes, then off for 10 minutes."

If you're thinking about a heating system for a new house, take a set of plans to your heating contractor showing a floor plan and an elevation plan of each outside wall. These plans should show the dimensions of all windows and doors, how much insulation will be installed, what type of windows will be used, the air tightness of the house (estimated air changes per hour), whether an air-to-air heat exchanger will be installed, and the heat exchanger's capacity. Adequate space should be provided for the furnace and for ductwork in a forced-air system, or for plumbing to accommodate a hot water system. Room for a furnace exhaust vent also should be included in the plans. The plans should show bathroom and kitchen vent fans, other gas appliances, and fireplaces and wood stoves.

The videotape "How to Calculate Design Heat Load" and an accompanying instructional booklet will help you calculate heat loss and properly size a furnace for your new house. They are available through the Montana Public Library Film Service (see address at the end of this publication). These calculations require some experience to apply to a real-life situation. An architect, heating contractor, or engineer can provide the professional assistance you need. Many of these professionals have computer programs that allow them to quickly do these calculations.

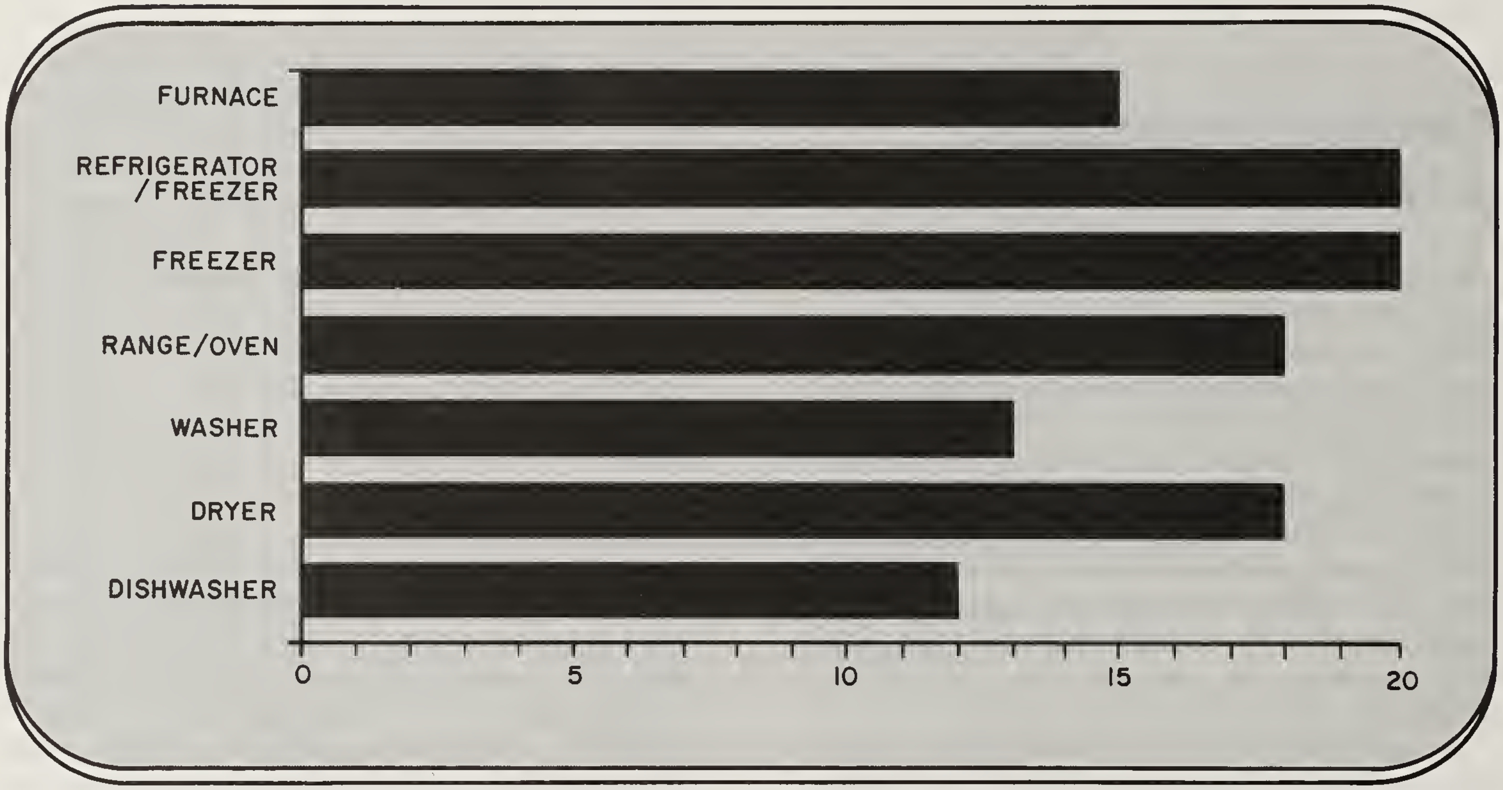
## Replacing Your Current Heating System

Before replacing a furnace to save on fuel bills, you should first consider other more cost-effective conservation measures. Caulking, weatherstripping, putting an insulating jacket on ductwork through unheated spaces, and possibly adding additional insulation to your house may be more cost effective than investing in a new furnace. An energy audit will show which conservation measures will be most effective in your home. You can request an energy audit from your local utility.

The average life of a furnace is 15 to 20 years. If a furnace is old and needs replacing anyway, then one of the newer, more efficient models may be a good investment. Replacing a newer furnace to save on fuel bills needs more careful consideration because the fuel savings over a number of years may not offset the cost of furnace replacement.

If a new furnace is needed, it might be possible to get by with a smaller capacity furnace than the old one. A smaller furnace will not cycle on and off as frequently and therefore is more energy efficient. Heating contractors and utilities can give advice on installing the correctly-sized heating system for your home.

Adding a new furnace to existing ductwork in your house could produce an unwanted side effect. With some of the newer furnaces whose blower fans move large amounts of air (1,200 to 1,400 cubic feet per minute), ductwork that is too small in diameter may produce whistling or howling noises as the air moves through. Setting back the fan speed to reduce air movement could burn out the heat exchanger prematurely and void the furnace warranty. A reputable contractor can determine if the ductwork size is adequate for the new furnace. If problems develop, the contractor may be able to recommend solutions that will cure the whistling noise, such as larger registers, or adding a new inlet or outlet duct.



**How long will furnaces and other major household appliances last? Here's the estimated life expectancies.**

Adapted from American Council for an Energy-Efficient Economy

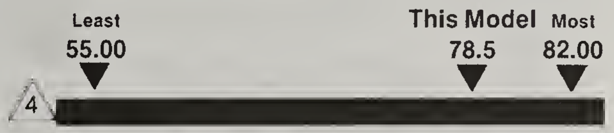
## Furnace Energy Guide Fact Sheet

Furnaces are required to carry a notice which directs buyers to an energy guide fact sheet. Consumers can use the fact sheet to compare the energy efficiency of different models. The rating system on the chart compares the efficiency of the furnace of interest with the least efficient and most efficient furnaces in its category. Unfortunately, the ratings do not show the efficiency of a heating system as a whole because of differences in ductwork and installation. However, the ratings do provide the basis for comparison between furnaces.

△1 Capacity: **42,000** Btu/hr (Output)

△2 Model A6043-2B
Electronic Pilot Ignition
Vent Damper

△3 Efficiency Rating (AFUE)



*Comparative National Average Yearly Cost ($) Information △6

△5

| Cost Per Therm of Nat. Gas | Btu/hr Heat Loss of Home (1,000's) | | |
|---|---|---|---|
| | 15 | 20 | 25 |
| 10c | $ 42 | $ 55 | $ 69 |
| 20c | $ 71 | $ 95 | $118 |
| 30c | $101 | $134 | $168 |
| 40c | $130 | $174 | $217 |
| 50c | $160 | $213 | $266 |
| 60c | $190 | $253 | $316 |

△1 Capacity of the furnace in Btu/hr (output).

△2 Furnace model number. (this model has electronic pilot ignition and vent damper identified.)

△3 The efficiency rating given in Annual Fuel Utilization Efficiency (AFUE).

△4 The bar scale shows the efficiency comparison of all listed furnaces (both this model and competing brands) for a given Btu/hr range. This model with 42,000 Btu/hr is compared to all gas furnaces in the 26,000 to 42,000 Btu/hr output range. The least efficient model rating in this range is on the left (55.00) and the most efficient on the right (82.00). The placement of this model (78.5) is proportionate to the least and most.

△5 The yearly operating cost is based on two variables; the cost of gas (per therm) and the heat loss of the home.

△6 The yearly cost information is based on the national average of 2080 heating load hours.

An example of a furnace Energy Guide fact sheet.

### Selecting the Best Value

The most efficient furnace might not be your best value. Generally, the higher the efficiency of a furnace, the higher the purchase price. In some cases, the fuel savings may not offset the additional cost of the furnace with the highest efficiency. Careful comparison shopping can save you money.

Great Falls Gas Company found energy savings ranging from 35-37 percent for furnace replacements with 93 percent efficiency, while savings after replacement with 85 percent AFUE hovered around 24 percent of heating costs. Another example is a large older home in Helena with an old coal stoker furnace which had been converted to natural gas. Roy Rowsey, a sheet metal contractor, removed and replaced the old unit with two high-efficiency furnaces. These units were "staged" so that only one furnace would operate during moderate temperatures. When the outside temperature dropped to 0 degrees F. or below, the second furnace would come on to satisfy the greater heating demand. This simple case resulted in a 50 percent energy savings to the homeowner. Utility bills of $200-$250 per month were reduced to $100 and less.

Some installations of new high-efficiency furnaces entail unexpected costs, such as the cost of installing new flues and drain pipes for removing condensate. In the Midwest, moisture problems have shown up in some homes where an old furnace has been replaced with a new high-efficiency model. When a new sealed combustion furnace was installed, the existing chimney flue was no longer needed and was plugged. Prior to furnace replacement, the chimney served as a good vent for household moisture. The old furnace used moist air from within the house for combustion. When the new furnace was installed and the chimney plugged, there was no longer a means to remove excess moisture from the house. After the problem was understood, a kitchen vent fan was added to the home to remove some of the excess moisture.

When switching fuels, careful comparison shopping can also show you which fuel is the best value. A recent study by the Northwest Power Planning Council compared the costs of heating with oil, natural gas, or electricity in heating systems in western Montana and northern Idaho. It concluded that, "At present, because oil and natural gas prices are generally lower than electricity prices, houses heated with fossil fuel-fired systems typically have lower annual energy costs, lower after-tax costs, and lower life-cycle costs than houses built to current codes that are heated with any electric system." Keep in mind that it's difficult to project future fuel prices, so these cost differences may change.

The appendix at the back of this book shows how to estimate heat bill savings that would result from switching to gas from another fuel. The appendix also helps you estimate which heating system is the best buy.

## Safety Considerations

An improperly installed furnace or gas appliance can cause sickness or death. As the flame in an appliance burns, it produces carbon dioxide, carbon monoxide, nitrogen dioxide, and other gases that can be harmful if not properly vented.

Insufficient oxygen causes incomplete combustion and produces carbon monoxide. Carbon monoxide is colorless and ordorless, and interferes with your body's ability to transport oxygen. The first symptoms of carbon monoxide poisoning include impaired vision and restricted brain function. Higher concentrations produce headaches, nausea, and dizziness. Irregular heartbeat and death can result from high concentrations or prolonged exposure.

Nitrogen dioxide irritates your respiratory system. At low concentrations, nitrogen dioxide can irritate your eyes and lungs. Exposure to nitrogen dioxide for long periods of time or at high concentrations may result in coughing and chest pain, and increases your chance of developing respiratory ailments. People with existing respiratory problems are most susceptible to its effects.

Older houses have cracks and crevices that allow enough air infiltration to supply oxygen to combustion appliances, fireplaces, or wood stoves, but a new, tightly constructed house may not. A roaring fire in a fireplace, the flame in a combustion furnace, or a vent fan can suck air out of the house at a rate of several hundred cubic feet per minute. If your house is tightly constructed, replacement air may not infiltrate fast enough and a slight vacuum might be created inside the house. The vacuum may be strong enough to suck air down the furnace flue, creating a backdraft. Backdrafting can pull harmful combustion gases, such as carbon monoxide and carbon dioxide, from the furnace or other combustion appliance into your home.

Tests in South Dakota on moderately tight new houses showed that a 2,460-square-foot, two-story home could develop a backdraft down the furnace flue when a 450-900 cfm Jenn-Air kitchen exhaust was operating. Other appliances that could create a problem when operated in combination are clothes dryers (roughly 250 cfm), bathroom vent fans (about 50 cfm each), and fireplaces or wood stoves (up to 400 cfm). The South Dakota researchers concluded that relatively small exhaust-air flows could cause backdrafting even in moderately tight homes.

Coordinating a fireplace with a self-venting range in a tight house was a learning experience for Sheryl and Jack Winkle of Billings. "We were warned that in a superinsulated house like this, the fireplace would backdraft if we turned on the range without cracking a window," Sheryl reflected. "Well, one night we did. The range exhausted so much room air that it started pulling outside air down the fireplace chimney. We had smoke everywhere."

## Testing For Backdrafts

You can easily determine if backdrafting is occurring in your home. The initial test determines if the furnace flue is obstructed. The second test determines whether appliances are pulling air down the furnace flue. The last test determines what effect a wood stove or fireplace has on backdrafting.

### First Test

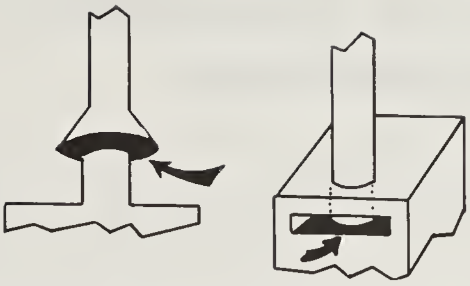
First, find the draft hood on your furnace of flue. This is the inverted cup or cone-shaped device on the flue just above the furnace. Do this test on a calm day when the windows and doors are closed, with no wood stoves or fireplaces burning, none of the vent fans running, and the clothes dryer turned off. Turn on the furnace and let it burn for 10 minutes or so to start a draft up the flue. Place a smoldering match or cigarette near the base of the flue below the draft hood. If smoke is drawn up the flue, the furnace is working fine. If not, the flue is blocked and should be cleared immediately.

### Second Test

For the second test, turn your furnace off and allow it to cool for an hour or so. No wood stoves or fireplaces should be burning. While the furnace is cooling, close the damper on any wood stoves or fireplaces and turn on all the vent fans in the house. Also turn on any combustion appliances, such as clothes dryers with vents to the outside and gas-fired hot water heaters that are vented through their own separate flue. Open any doors into the furnace room and/or basement. Close all windows. Turn on the furnace and let it burn for 10 minutes. Place a smoking matchstick near the base of your furnace draft hood. If smoke is not being drawn up the furnace flue, backdrafting is occurring and could lead to problems. Your house needs more ventilation.

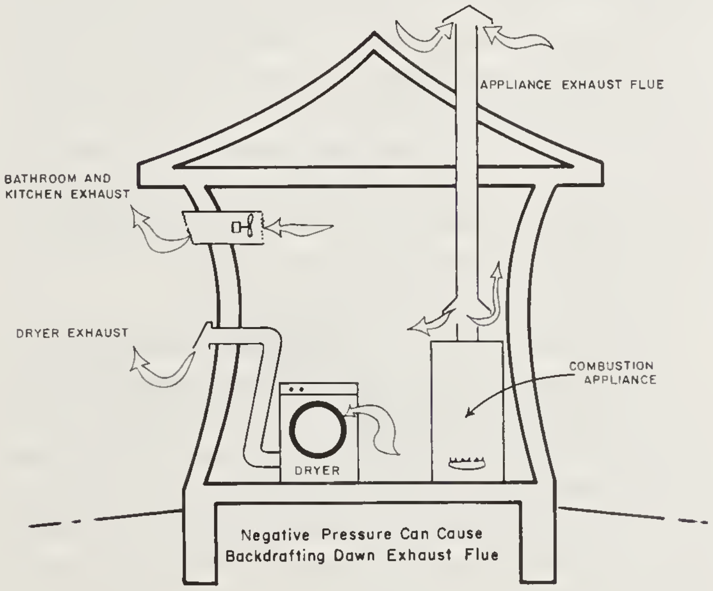
### Third Test

Now light a fire in your wood stove and/or fireplace. When a roaring fire is going, repeat the second test. Again, if smoke from a burning match is being drawn up the furnace flue, there is not a problem; however, if the smoke from the match is being blown back into the room or if the smoke is simply not being sucked into the flue, you should provide additional ventilation to the furnace. Open a window into your furnace room until more permanent ventilation can be provided.



**Typical furnace draft hoods. For backdrafting tests, a smoldering match is held near the opening as shown by the arrows.** (Adapted from ***Combustion Air for Safe Heating,*** Minnesota Department of Energy Planning and Development)

There are several solutions to backdrafting problems. A heating system with induced or forced draft is likely to remain free of backdrafting. These systems use fans to blow furnace exhaust up the chimney flue. Other new furnace designs such as direct-vent or sealed combustion use only outside air for combustion. Direct-vent or sealed combustion furnaces can have power drafts or natural drafts, but the system does not have a draft hood and is isolated from the rest of the house. Publications by the Minnesota Energy Office and the U.S. Department of Energy (listed at the end of this booklet), as well as building codes, provide detailed discussions of how to provide supplemental combustion air to gas-fired furnaces and hot-water heaters.


APPLIANCE EXHAUST FLUE
BATHROOM AND KITCHEN EXHAUST
DRYER EXHAUST
COMBUSTION APPLIANCE
DRYER
Negative Pressure Can Cause Backdrafting Down Exhaust Flue

**Operation of exhaust vents in tightly built houses may create a slight vacuum indoors, pulling harmful gases down the furnace or chimney flue into the home.** (Adapted from ***Combustion Appliances in Energy Efficient Homes.*** DOE/CE-0153)

## Furnace Installation Considerations

If you are installing a new furnace or replacing an existing one, understanding the relevant building codes will help ensure a safe installation. If you are installing or replacing a furnace, and you live in one of the 54 Montana local government jurisdictions that have adopted nationally recognized building codes, you may be required to obtain a building permit from the inspector's office. Contact your local building inspector for information on required permits and minimum clearances, ductwork design, and venting requirements. If you live in an area where single-family dwellings do not require building permits or inspections, you can buy a copy of the codes from the Montana State Building Codes Bureau (their address is given at the end of this booklet). The code book will provide useful information on the accepted methods for safe installation of furnaces, ductwork, and vents. Elmer LaZure, with the Montana Building Codes Bureau, notes that most violations of the Uniform Mechanical Code relate to proper clearance from combustible materials (Chapter 9, UMC) and providing adequate combustion air to fuel-burning appliances (Chapter 6, UMC).

Clearances around a furnace or boiler must follow the manufacturer's recommendations. Most furnaces or boilers will have an Underwriters Laboratory (UL) or American Gas Association (AGA) label of approval, and these testing agencies require these clearances before they certify such equipment.

Codes do not allow propane furnaces or appliances to be installed below grade unless a gravity vent is provided. A gravity vent slopes away from the furnace or appliance to the outside. If there is a leak, this vent drains propane, which is heavier than air, from the house. It is not possible to provide such a vent for a propane furnace in a standard basement. Chapter 22 of the Uniform Mechanical Code lists the requirements for installation of L.P.G. equipment.

Exhaust vents, which carry combustion gases away from a furnace, must be located at least 6 feet from a window. This is why many contractors still prefer to vent furnace flues through the roof even though some of the newer furnaces can be vented through the side of the house. Ice build-up might be a problem on vents through the side of the house. Vents, connectors, and ductwork for combustion gases must not extend into or through any air duct or plenum.

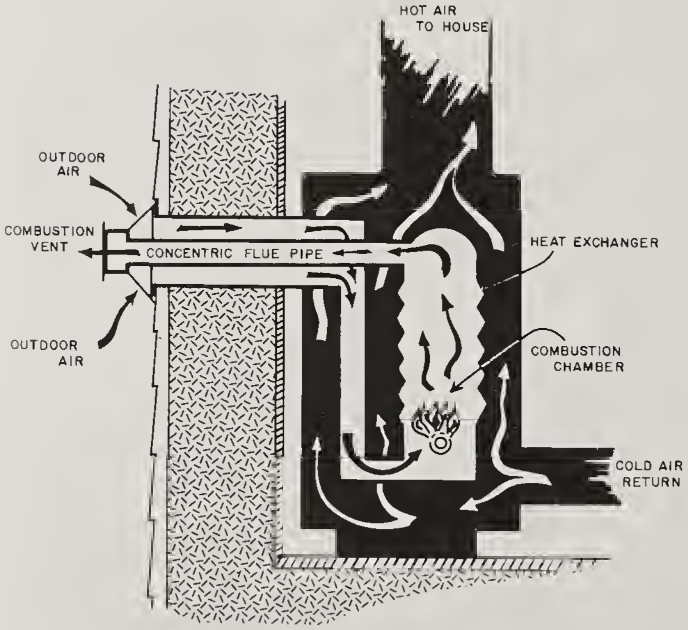
The installation of gas-burning equipment is prohibited in locations such as bathrooms, bedrooms, closets or any enclosed space with access only through such a room or space, and hazardous locations. This means that a furnace or boiler cannot be located in or next to a bedroom, bathroom, or closet if the only entrance to the furnace is through these rooms. If furnaces are supported on the ground, they must rest on a cement slab extending at least 3 inches above the surrounding ground level. You must provide access to furnace rooms with a door not less than 2 feet in width and large enough for removal of the largest furnace in that room. You also must provide an unobstructed working space extending at least 30 inches in front of the entire firebox for servicing equipment.

You can obtain more information about the requirements of local building codes and the safe installation of heating systems from your local utilities, building inspectors, or reputable heating, air conditioning, or sheet metal contractors.

## Providing Adequate Combustion Air

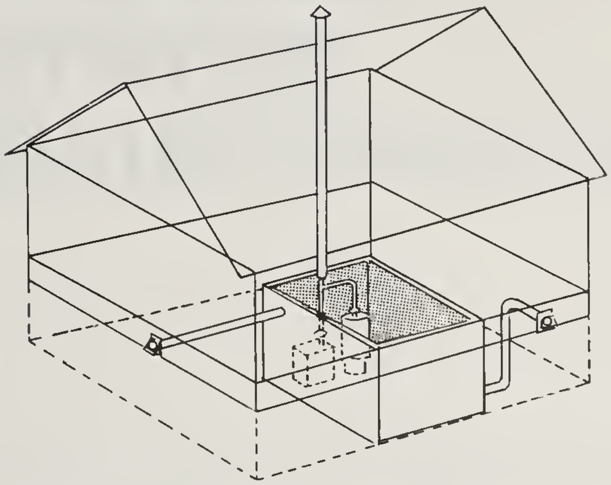
There are at least five ways to provide adequate combustion air when installing new furnaces. One way is to install a sealed combustion unit. This type of furnace supplies combustion air from an outside vent directly to the combustion chamber of the furnace. Exhaust gases are ducted directly outside. There is no draft hood and no chance of backdrafting down the furnace flue.

If you are installing a direct vent (sealed combustion) furnace but also have other gas appliances, wood stoves, or fireplaces, you may still have to introduce supplemental combustion air for these other appliances. This is especially true if you have vent fans in a kitchen or bath.



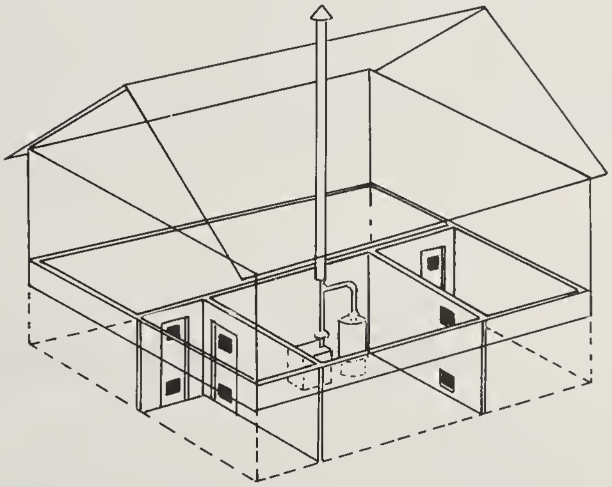
**A sealed combustion unit will supply combustion air from an outside vent directly to the combustion chamber of the furnace, with exhaust gases ducted directly outside.** (Adapted from ***Combustion Appliances in Energy Efficient Homes.*** DOE/CE-0153)

The second way to provide adequate combustion air is to build a small room around the furnace and other combustion appliances, such as the hot water heater and gas clothes dryer. Air in this room is isolated from the rest of the house. Combustion air is then ducted to this room from a vent on the outside of the house. In this arrangement, backdrafting is prevented because no air from the utility room can be drawn into the main living area.



**Building a small room around the furnace and other combustion appliances.** (Adapted from ***Introducing Supplemental Combustion Air to Gas-Fired Home Appliances.*** DOE/CE/15095-7. December 1983)

A third way to provide combustion air to a furnace and other combustion appliances is to draw indoor air through vents in walls and doors of adjacent rooms into a utility room. However, in tightly constructed houses, there may not be enough infiltration to provide adequate amounts of combustion air from adjacent rooms.



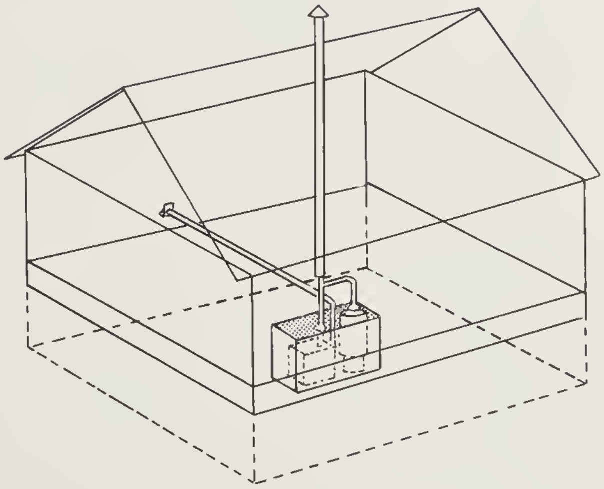
**Using adjacent rooms for additional combustion air.** (Adapted from ***Introducing Supplemental Combustion Air to Gas-Fired Home Appliances.*** DOE/CE/15095-7. December 1983)

Whether supplemental air comes from indoors through vents in walls or from outdoors, building codes state that half of the supplemental air must be introduced within the upper 12 inches of the room and the other half within the lower 12 inches of the room. This can be done with a single duct with a louvered vent at the top of the room and an open duct run at the bottom. The minimum size of supplemental air openings is 3 inches in cross section. The openings must terminate not less than 6 inches in front of the furnace firebox (One and Two Family Dwelling Codes, 1983).

The required size of ducts and openings to appliance rooms varies with the Btu rating of furnaces and combustion appliances in that room, the volume of the room, and the volume of appliances. The size of ducts varies from 1 square inch of total free area for each 1,000 Btu to 1 square inch for each 5,000 Btu. You should refer to Chapter 6 of the Uniform Mechanical Code for more information about the proper sizing of ductwork for providing combustion air. Remember to separate combustion air ductwork from plumbing to prevent freezing.

A fourth method of providing combustion air to the furnace is to duct outside air to locations near the furnace. The disadvantage of ducting outside air to a point near the furnace is that cold air can spill across the floor in the basement or other room where the furnace is located.

The last way to introduce supplemental combustion air while slowing cold air flow into a room is to build an open-topped partition around the furnace and other appliances. Outdoor combustion air is then ducted into the lower part of this partition. See the publication Introducing Supplemental Combustion Air to Gas-Fired Home Appliances for more details on these installations.



**Building an open-topped partition around the furnace and other combustion appliances.** (Adapted from ***Introducing Supplemental Combustion Air to Gas-Fired Home Appliances.*** DOE/CE/15095-7. December 1983)

# FURNACE AND HEATING SYSTEM MAINTENANCE

When was the last time your furnace had a thorough cleaning and tune-up? Since gas furnaces tend to operate trouble free for many years, you can easily forget to have them checked and tuned up on a regular basis. On one service call to a home where the furnace was operating but not delivering heat, a customer service worker found a filter completely plugged with dust. The hot air could not get through the filter into the distribution system. Utility customer service workers often find improper combustion because the natural gas and air mixture is either too rich (too much natural gas) or too lean (too much air). Either problem results in too little warm air delivered into the home.

Regular maintenance and cleaning of your heating system and furnace are cost-effective methods for reducing heating bills. You can regularly do several simple cleaning tasks to help your heating system run more efficiently. Furnace adjustments and repairs should be performed by a qualified technician. A regular maintenance program can lengthen the life of your furnace and help avoid costly and inconvenient breakdowns.

## What You Can Do

The efficiency of any forced hot-air heating system can be increased by regular cleaning of all accessible parts where air circulates and dust accumulates. Both heating registers and return-air grilles should be free of dust and clear of drapes, furniture, or rugs. Vacuum your registers, grilles, and accessible ductwork at least twice yearly, and especially at the start of a heating season.

Examine exposed ductwork for leaks. Seal duct joints and leaks with duct tape. Cover ducts that run through unheated spaces such as attics or crawl spaces with duct wrap, batt, or blanket insulation to reduce heat loss. Insulate ducts to at least R-7 and place a vapor barrier on the outside of the insulation.

Besides cleaning and checking ductwork and registers, you also can perform several simple maintenance tasks on gas furnaces. Before starting these jobs, refer to the maintenance manual for your furnace, close the main gas shut-off valve and shut off the electricity to the furnace.

You can usually remove exterior panels from your furnace to make the burner unit and heat exchanger accessible. Vacuum exposed surfaces to remove accumulated dust and dirt. Check the air filter several times a year. Replace dirty fiberglass filters. Aluminum or plastic filters can be washed, rinsed, dried, and reinstalled. If the furnace blower and blower motor are not prelubricated and sealed, add a few drops of oil. Check your furnace manual for required maintenance. Don't forget to also clean and oil the auxiliary fan system if your furnace or boiler has one.

## Furnace Tune-ups

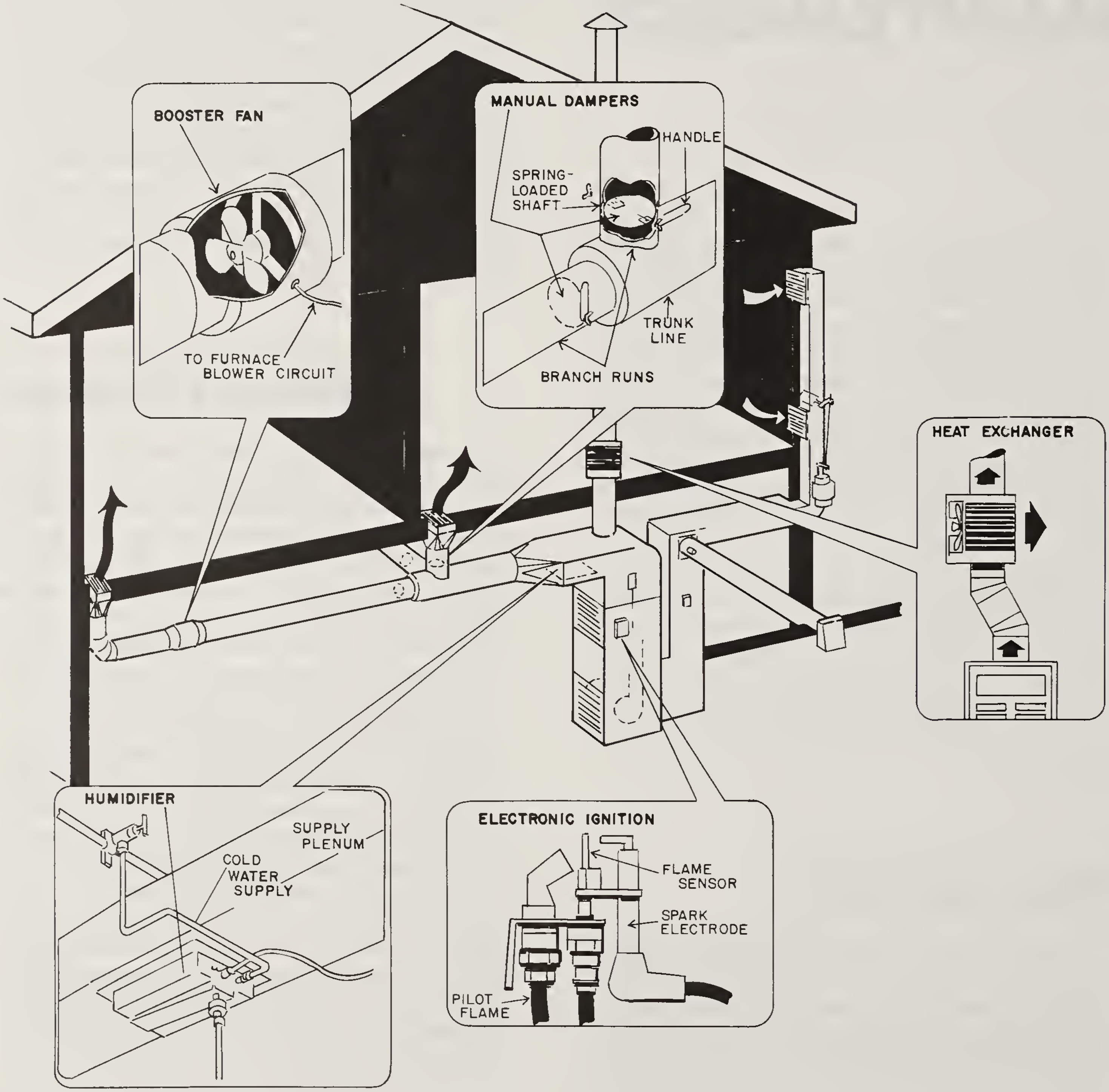
A service technician can perform more complicated maintenance tasks on your furnace to keep it running efficiently. These tasks can include checking the operation of the main shut-off valve, pressure regulator, safety control valve, the alignment of blower and motor pulleys, and the wear and amount of tension on the fan belt. Thermostat contacts can be cleaned and adjusted for more efficient operation. The pilot light assembly can be cleaned if the gas orifice has become plugged. Lastly, gas burners can be cleaned and their air supply adjusted to produce a clean, even flame.

A service technician, utility representative, or heating contractor can also check your furnace's combustion efficiency and make adjustments as necessary, increasing its efficiency and saving you money on heating bills. Combustion efficiency tests are available as part of an energy audit performed by local utilities. A combustion efficiency test will tell you the steady state efficiency of your furnace. It is a measure of how efficient your furnace operates and should be higher than the AFUE rating, which also measures off-cycle losses during a heating season. Refer to the article "Do You Really Know Your Furnace's Efficiency?" Listed at the end of this publication for more detailed information on combustion efficiency tests.

## Heating System Upgrades and Retrofits

Several "add-ons" or retrofits are available for heating systems. Initial cost, ease of installation, and fuel savings will vary for all these devices. Improperly installed retrofits can be a safety hazard. Problems with retrofits are usually traced to failure to look at the entire heating system. A qualified contractor will consider the ductwork layout and flue or chimney changes needed when installing a retrofit.

Several precautions should be taken before installing any heating system or furnace retrofit. For furnace retrofits, check whether the device has been certified or approved by national testing laboratories such as Underwriters Laboratories or the American Gas Association. Determine if retrofits will void your furnace warranty or require changes in your fire insurance policy. Work with a qualified contractor who is familiar with heating systems and local building codes when furnace or building modifications are required. And lastly, schedule regular furnace maintenance and safety inspections to ensure that installed retrofits are operating properly.



**Some furnace retrofits can increase a furnace's efficiency and save money.** (Adapted from ***Popular Science,*** October 1984)

## Furnace Retrofits

### Flue dampers

Dampers can save you money by sealing off the flue when the heating unit is not operating, reducing heat loss caused by chimney drafts. They are most appropriate for heating units with large off-cycle losses, such as boilers with large reservoir tanks. Savings will increase if a heating unit has high operating temperatures (such as steam boilers), high thermal mass (such as a hot water reservoir), an unobstructed path up the flue for combustion gases, or is located in a heated part of your home.

Electrically-activated dampers are electrically-coupled to a thermostat or gas valve, and will open when combustion is occurring. A full-closure damper on a gas unit will require removal of the pilot light and replacement with an intermittent ignition device. If not removed, the pilot light's combustion gases would accumulate in the home and could condense in the furnace rather than escaping, eventually corroding the furnace or boiler and causing a safety hazard.

Thermally-activated dampers are appropriate for gas heating systems. On oil-fired systems, accumulations of soot may interfere with damper operation. These dampers are activated by combustion gases themselves, opening when heat causes them to flex. This allows the hot gases to escape. Unlike the electrically-activated models, they will not fully close following combustion. Thermally-activated dampers cost less than electrically-activated models and are easier to install. However, they will also save less energy.

### Electronic ignition or intermittent ignition device

These replace a continuously burning pilot light. By using an electronic spark for ignition, they can save anywhere from 4-6 percent per year of your annual heating costs. Intermittent ignitions are designed to do three things: (1) automatically ignite gas at the main burner; (2) prove the presence of a pilot flame before allowing gas flow to the main burner; and (3) prevent gas flow if the pilot flame is not lit.

### Furnace derating

Houses that have been weatherized by adding insulation, storm windows and doors, caulking, or weatherstripping may require less heat than provided by the existing furnace. An oversized furnace may be a candidate for "derating" or modification to reduce its capacity. This is typically done by reducing gas pressure to the furnace and/or replacing the burner orifice with a smaller one. A smaller orifice may require flue modifications, so be sure to check with a qualified contractor to determine the amount and type of derating appropriate for your heating system. Savings will vary with type and size of furnace and heating load. Don't try this furnace modification yourself. A utility representative or contractor should make this type of modification.

### Flue heat exchangers

These secondary heat exchangers are installed in the vent between the furnace and draft hood. They extract additional heat from furnace flue gases and vent it directly into the house. By doing this, they increase the furnace's combustion efficiency. They also decrease the flue gas temperature, which can lead to condensation and corrosion in the flue. Flue heat exchangers reduce the draft of combustion gases through the vent system, so a safety inspection should be done following installation to ensure that the flow of combustion gases is still adequate.

### Flue restrictors

A flue restrictor consists of a metal plate fitted into the furnace flue pipe. It reduces the inside diameter of the flue, and like the dampers discussed above, reduces off-cycle heat losses by reducing the amount of heat escaping up the chimney. Flue restrictors are most appropriate when a flue is oversized. For any installation, check to be sure that the reduced flue diameter still meets building codes. Flue restrictor installation should be done by a qualified contractor. Do not try to double the amount of restriction to save money. Such changes can restrict the flow of harmful combustion gases.

### Variable flow gas valves

Variable flow or modulating gas input valves are attached directly to the gas lines leading to the furnace's burners. The valve is controlled by a voltage regulator that measures the difference between the actual and desired inside temperature in a house. As this difference increases, the valve opens to allow more gas into the burners. During the heating season, off-cycle or stand-by losses can be reduced with this retrofit. However, if the amount of combustion air is not regulated along with the burner flame, furnace efficiency may decrease. Some contractors point out that these are very expensive to install and suggest that little if any savings can be expected over the life of the furnace.

### Burner cyclers

Burner cyclers operate as an additional temperature controller in the furnace to cycle the furnace more frequently than the thermostat calls for. They are marketed as energy savers, extracting excess heat for circulation to your house. However, furnaces are designed and controls set to provide the proper cycling. Changing the operating characteristics of a furnace may cause condensation and corrosion within the furnace, and void the furnace warranty. Check with your furnace dealer or local utility before installing this retrofit.

### Boiler reset controls

Reset controls or temperature programmers are good retrofits for hot water systems. Rather than maintain boiler water at a fixed temperature, they "reset" the boiler water temperatures to lower levels as outdoor temperatures rise. They typically consist of two sensors, one of which is located outdoors with the second located on the supply pipe next to the boiler. These reset controls are most effective in areas where temperatures fluctuate frequently during the winter.

## Additional Heating System Retrofits

### Thermostats

Thermostat setbacks offer one of the simplest methods for saving energy and reducing heating bills. Savings typically amount to 1 percent for every degree the setting is lowered for an eight-hour period. The least expensive method is to manually reset the thermostat yourself when leaving home or at night. This method will cost nothing if you are willing to make the adjustments and put up with a chilly house in the morning when you rise.

Electromechanical thermostats provide a second option for regulating setback temperatures. They use a clock-timer to change from one temperature setting to another at a designated time. These have proven convenient and reliable, and work well with any gas-fired heating system. Automatic and setback thermostats are also discussed in The Montana Energy Book published by DNRC.

Computerized thermostats and programmable controllers are the most recent option for regulating temperatures in your home. However, one major consumer testing group found problems with many models. These problems included interrupting the voltage in the control circuit during the furnace's on-cycle, models that are incompatible with control circuits on heating systems, and difficulty in programming the controller. Programmable thermostats should be carefully evaluated for ease of operation and compatibility with your heating system. Most manufacturers have lists of thermostats that are compatible with their equipment.

### Humidifers

Increased humidity levels in a house can make you feel warmer at lower temperatures. You can install add-on humidifers to your existing forced-air heating system. Newer add-on models are self-flushing and require a drain line. Humidifers can also be purchased as stand-alone units.

### Heating duct additions

For forced-air heating systems, both dampers and booster fans are available as relatively inexpensive add-ons to increase heating efficiency. Dampers can be installed in supply ducts, reducing airflow to overheated rooms and making more heat available to cooler rooms. Manually-controlled dampers should be installed where they will be easily accessible. More expensive motorized dampers are appropriate for inaccessible areas where excess heat is available, such as a room with a wood stove. These dampers are controlled by a switch or thermostat.

Booster fans can be installed in long sections of ductwork that supply too little heat to distant rooms. They should be connected to the furnace blower circuitry so that they operate in conjunction with this blower.

### Thermostatic radiator valves

Standard steam and hot water radiator valves can be replaced with thermostatic valves for more precise temperature control. Thermostatic valves will provide temperature control on individual radiators, functioning much like dampers on hot air ducts. Remote sensors that are not mounted directly on the radiator's control knob should be located away from windows to avoid drafts.

# OTHER GAS APPLIANCES

## Water Heaters

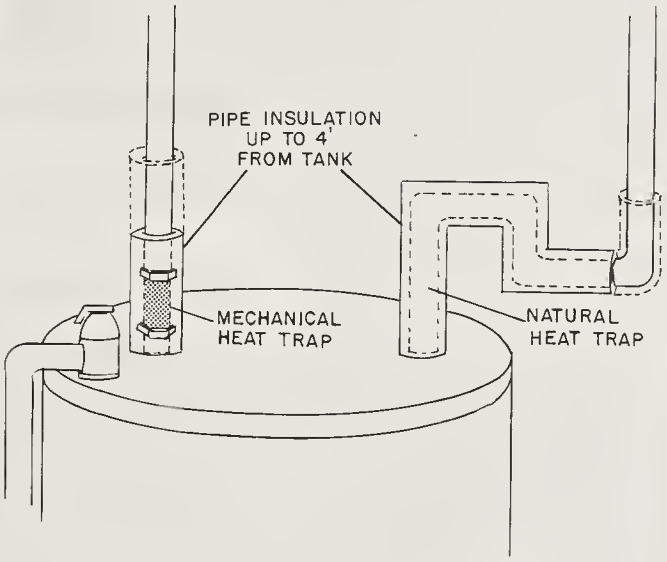
Hot water. Available on demand in large quantities. We take it for granted every day. Only when the water heater breaks down or needs to be replaced do we give it a second thought. Yet, water heaters are the second largest energy consumers in the typical home, averaging between 15 and 20 percent of a family's energy budget. Several options are available to reduce these costs, ranging from relatively inexpensive add-ons to your present water heater, to replacement of your system with a more efficient one. Becoming familiar with these options and how well they match your needs will help you make an informed decision.

Conventional gas-fired water heaters have burners beneath the storage tanks, with thermostats keeping water at a set temperature. Energy losses result from maintaining a high stored-water temperature 24 hours a day, even when it's not needed. Energy losses also occur as hot water cools in uninsulated piping.

More energy-efficient new models have additional insulation to reduce these "stand-by" losses. Some gas-fired water heaters have a submerged heating chamber within the tank to provide maximum heat transfer. Other energy-efficient features available include hot-surface igniters that replace pilot lights, and microprocessor-controlled combustion. Condensing-type water heaters have efficiencies up to 90 percent. They capture additional heat from the water vapor in combustion gases through the condensation process. Like condensing furnaces, these water heaters require a drain tube for the condensate, and can be vented through a side wall if local building codes permit. Sealed combustion gas-fired water heaters that use outside air for combustion are also available. These would be a good choice for tightly built homes or when replacing an electric water heater when no chimney is available. If replacing your water heater is necessary, the more energy-efficient models may be a better long-term investment.

### Low-cost Add-ons

Several low-cost conservation measures can trim your water heating bills. These include insulating the water tank and hot water pipes and installing low-flow shower heads. An alternative to insulating pipes is installation of thermal traps or check valves. These control the flows of hot and cold water through the piping, and return hot water to the heater before it cools in the pipes. These conservation measures and others are discussed in greater detail in The Montana Energy Book published by DNRC.



**Installing thermal traps or check valves and insulating hot water pipes are low-cost conservation measures for trimming water heating bills.**

If your household needs hot water only at certain times of the day, automatic set-back devices or timers may provide some savings. These are available for both electric and gas water heaters and can be installed by homeowners with good instructions and some knowledge of wiring. Tests have shown that savings of up to one-third on your water heating bill are possible with these devices, heating hot water only for those times when it is needed.

### Buying a New Water Heater

An informed purchasing decision can save you a significant amount of money in operating cost over the estimated 7- to 10-year life of a water heater. Using the heater in an energy-conscious way will save you even more money.

Four criteria should influence your choice of a water heater. Energy Guide Arithmetic will show you how to combine these criteria to select the best water heater for your needs.

1. **Peak hour demand.** The busiest 1-hour period of the day for your water. The heater selected should be able to provide enough hot water to meet this peak demand. It is a common practice to replace a water heater with one of the same tank capacity. This could be a costly error if the old tank was larger than necessary for your needs. Clearly, the morning and evening demand for hot water is very different in the household of a retired couple than for a family with three or four children., To find the right size water heater for your household's bathing, laundry, and dishwashing needs, estimate your peak hour demand/first-hour rating from the following table (Table 2) developed by the Gas Appliance Manufacturers Association. Use this rating, not tank capacity, in buying a new water heater.

2. **Energy efficiency rating.** The next step in your purchase decision should be to compare the energy efficiencies of different fuel types, unless you have no choice, such as in an all-electric home. Operating cost data can be found on the yellow and black Energy Guide Label that federal law requires to be posted on every water heater for sale.

The Energy Guide Label tells you how the model you're considering performs relative to two extremes: the model that uses the most energy and the model that uses the least energy. A "best buy" should always be on the low side in energy consumption, though the specific needs of the user determine which model would best match the intended purposes. You should always consider how you use certain appliances when you are trying to determine which model is best for you. A young family with several children uses a water heater more than a single homeowner. The same energy-efficient appliance may be underused by the single homeowner who could easily scale down capacity requirements. Also, DNRC advises that any so called "energy efficient" appliance isn't a best buy if it takes more than 7 years to pay for itself in savings.

3. **Initial cost.** This can range from a few hundred dollars to more than one thousand dollars, depending on capacity, efficiency, and installation expense.

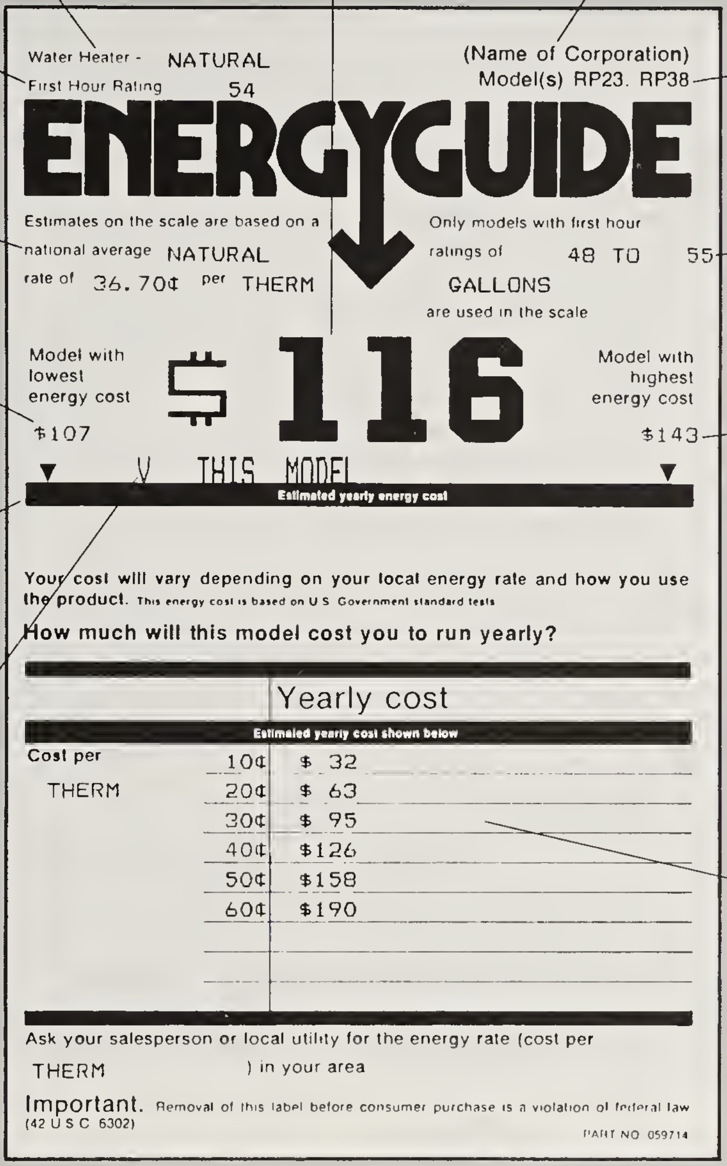
4. **Operating costs.** These will vary with type of fuel used and efficiency of the heater. Operating costs and efficiency ratings for hundreds of models can be obtained from the Gas Appliance Manufacturers Association biannual directory of certified water heater efficiency ratings. Local utilities also can provide product information. (See references at end of this publication.)

**Table 2. Calculating Peak Hour Demand**

| Use | Avg. gals. hot water per use | | Maximum times used during 1 hour | | Maximum gals. used in 1 hour |
|---|---|---|---|---|---|
| Shower | 20* | X | | = | |
| Bath | 20 | X | | = | |
| Shaving | 2 | X | | = | |
| Hands & face washing | 4 | X | | = | |
| Hair shampoo | 4 | X | | = | |
| Hand dishwashing | 4 | X | | = | |
| Automatic dishwashing | 14 | X | | = | |
| Food preparation | 5 | X | | = | |
| Wringer clothes washer | 26 | X | | = | |
| Automatic washer | 32** | X | | = | ____________ |
| | Total (peak hour demand) | | | = | |

* Reduce to 12 gallons if using water-saving shower head.

** Reduce to 0 gallons if using cold water washing procedure.



Water Heater - NATURAL
First Hour Rating 54

(Name of Corporation)
Model(s) RP23. RP38

**ENERGYGUIDE**

Estimates on the scale are based on a national average NATURAL rate of 36.70¢ per THERM

Only models with first hour ratings of 48 TO 55 GALLONS are used in the scale

Model with lowest energy cost $107

**$116**

Model with highest energy cost $143

THIS MODEL

Estimated yearly energy cost

Your cost will vary depending on your local energy rate and how you use the product. This energy cost is based on U.S. Government standard tests

How much will this model cost you to run yearly?

| | Yearly cost |
|---|---|
| | Estimated yearly cost shown below |
| Cost per THERM 10¢ | $ 32 |
| 20¢ | $ 63 |
| 30¢ | $ 95 |
| 40¢ | $126 |
| 50¢ | $158 |
| 60¢ | $190 |

Ask your salesperson or local utility for the energy rate (cost per THERM) in your area

Important. Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302)

PART NO. 059714

Type of appliance.

*Estimated* annual operating cost for this model only.

Name of manufacturer and model number of the appliance on which this label appears.

The first hour rating.

National average unit cost of fuel.

Estimated annual operating cost for the model in this size range that costs *least* to operate.

Scale showing lowest and highest estimated operating costs for models within this size range. These models represent different brands, not just those of the company listed in the upper right-hand corner.

Where the estimated annual cost of this particular model falls in comparison to all other models in this size range.

All model numbers are listed if the label applies to more than one model.

All brands and models compared in the scale on this label fall within this range of first hour ratings.

Estimated annual operating cost for the model in this size range that costs *most* to operate.

A grid to help determine more closely the customer's operating cost based on local utility rates and use habits.

An example of an Energy Guide label for a water heater.

## Energy Guide Arithmetic

If you're shopping for the best buy in new 40-gallon water heaters with comparable first-hour ratings (peak-hour demands), you can use the black and yellow Energy Guide Labels to arrive at an informed purchase decision.

Let's say you are comparing three different water heaters. Model A costs $143 annually to operate but is least expensive at $240. Model B is the most expensive at $280 but also has the lowest annual operating cost at $107. Model C is in the middle with an annual operating cost of $116 and a purchase price of $255.

Step 1. Select the least expensive and least efficient model as a basis for comparison with the other models you are considering. In this example it would be Model A.

Step 2A. Figure annual energy savings for the other models based on Model A. Subtract lower values from higher values.

For Model B: $143 for Model A —$107 for Model B = $36 annual energy savings
For Model C: $143 for Model A —$116 for Model C = $27 annual energy savings

Step 2B. Figure purchase price difference for the other models based on A.

For Model B: $280 for Model B —$240 for Model A = $40 purchase price difference
For Model C: $255 for Model C —$240 for Model A = $15 purchase price difference

Step 3. Estimate the amount you could save over the life of the water heater by purchasing Model B or C rather than Model A. This is done by multiplying the annual energy savings found in Step 2A by 8.2 and subtracting the purchase price difference found in Step 2B.

A multiplier of 8.2 is used to convert annual energy savings over the life of the water heaters to equivalent one-time values for comparison. A value of 8.2 assumes a 10-year life for the appliance and a long-term rate of return (adjusted for inflation) of 4 percent. Any other multiplier could be used from Table 2 in the Appendix at the back of this book by specifying the appliance's life in years and an anticipated long-term rate of return.

Savings for Model B compared to Model A = (8.2 x $36) - $40 = $255.20
Savings for Model C compared to Model A = (8.2 x $27) - $15 = $206.40

Step 4. Rank the lifetime savings from Step 3 from highest to lowest. Model A will have a value of zero since you used it as the basis for comparison. The model with the highest lifetime savings will be the best buy.

Model B - $255.20
Model C - $206.40
Model A - -0-

Model B is the best buy in this example, since its lifetime savings compared to Model A are highest and more than make up for its higher purchase price.

# Other Water Heating Options

You can consider other energy-saving technologies when replacing your water heater. Some of the newer technologies can be installed as additions to an existing system, while others may require major changes.

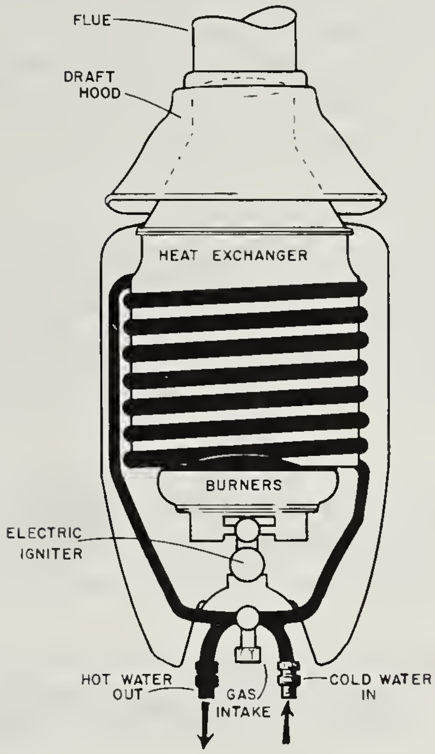
### Indirect-fired Water Heaters

Like the integrated hydronic heating systems described earlier, these water heaters are integrated with home heating systems, "borrowing" heat from another source, typically a boiler. They are indirectly fired from another combustion unit and lack a pilot light and the need for combustion air. These water heaters are generally more durable than direct-fired heaters, but cost 2 or 3 times as much.

Two types of indirect-fired water heaters are described in the earlier section on integrated hydronic heating systems. Two other types of indirect-fired water heaters are also available. The first type has a hot water coil submerged in the water storage tank. The coil is connected to a nearby boiler, and as hot boiler water circulates through the coil, heat passes to the cooler water of the storage tank. The second type is referred to as a double tank, or tank-within-a-tank. For this type of configuration, hot boiler water typically circulates through the outer tank, heating the cooler domestic water in the inner tank.

## Tankless Water Heaters

If you need a constant supply of hot water, consider a tankless water heater. Also called "demand" or "instantaneous" water heaters, these function without a storage tank. Activated by flow sensors when a hot water spigot is turned on, burners in a gas unit or a heating element in an electric unit instantly heats water as it is drawn through the heater for use.



**A gas-fired tankless water heater.** (Adapted from ***The Family Handyman,*** December 1984)

Tankless water heaters come in varying sizes and capacities and can be installed in various configurations: (1) to replace a regular water heater, (2) as single point-of-use installations anywhere in the house, or (3) as boosters to a standard storage heater.

Tankless water heaters typically cost from $200 to $800 compared to $100 to $400 for conventional water heaters. Installation costs also may be higher. Gas-fired tankless heaters require gas hook-ups and a vent to the outside, and many electric models require 220-volt wiring. Safety features such as pressure relief valves and temperature sensors to avoid overheating also should be included.

Higher initial costs may be offset by lower operating costs over the life the unit. Depending on the efficiency of the system replaced, fuel prices, and water-use patterns, savings of 10 to 20 percent per year are possible. Additional savings can result from the longer life of tankless heaters — 20 or more years compared to 10 for most conventional water heaters.

Early models of tankless heaters had a fixed heat output — the higher the water flow, the cooler the water. Newer models have modulating heaters sensitive to both the temperature and rate of water flow. Some larger gas models can be thermostatically controlled, providing hot water at a constant temperature regardless of incoming water temperature.

Tankless water heaters supply lower water-flow rates, typically 2 to 3 gallons of hot water per minute compared to 5 to 7 for conventional water heaters, and may require some changes in use of hot water. For some installations, hot water use may have to be coordinated, avoiding simultaneous shower and dishwasher use, for example. Another option is to keep a conventional water heater and install a tankless heater as a point-of-use booster for the dishwasher. You might consider installing several point-of-use tankless heaters when hot water is needed at opposite ends of a house.

When installing any heat-producing appliance, you should follow installation clearances specified in the building codes. Standard installation clearances for gas appliances are shown in Table 3. Remember that all storage-type water heaters must be provided with an overheating safety device in addition to the primary temperature controls to meet code requirements.

**Table 3. Standard Installation Clearances for Heat-Producting Residential Appliances***

| | Clearance (in inches) | | | |
|---|---|---|---|---|
| **Appliance** | **Above top of casing or appliance** | **From front** | **From back** | **From sides** |
| Gas water heaters (200° F) | 6 | 18 | 6 | 6 |
| Gas ranges and cooking stoves (vented or unvented) | 30 | — | 6 | 6 |
| Gas clothes dryers | 6 | 24 | 6 | 6 |

* Adapted from Council of American Building Officials: One and Two Family Dwelling Code, 1983. Building Officials and Code Administrators International, Inc Some manufacturers may list slightly different clearance recommendations. Where values differ, follow the manufacturer's recommended clearances. Clearances listed in the table may be reduced somewhat by following specifications listed in the building codes.

# Gas Ranges

Compared to other major appliances, ranges are not heavy energy consumers. Convenience and performance features rather than energy efficiency will typically guide your selection of a range. After selecting models with the features you think important, compare energy efficiencies. Gas ranges will have lower operating costs than electric ranges, based on the lower cost of gas.

Gas ranges give off nitrogen oxides, carbon dioxide and monoxide, and other products as gas is burned. These combustion products are released into the home's atmosphere unless ventilation is provided. Although there is no law regulating indoor pollution in private homes, measurements show that the Environmental Protection Agency (EPA) outdoor air standard for nitrogen oxide (0.05 ppm) is sometimes exceeded in the home. In kitchens with unvented gas stoves, nitrogen oxide levels typically vary form 0.025 to 0.08 ppm.

Several options are available for reducing indoor air pollution caused by cooking with a gas range in the home. Improperly adjusted burners produce a yellow flame and increase pollution concentrations. Adjust the flame so it burns blue. A properly adjusted flame should result in minimal pollution. A range hood vented directly to the outside can effectively remove much of the nitrogen oxide and moisture created by cooking. Range hoods that are not vented to the outdoors generally do not remove nitrogen oxides. Opening a window also can reduce nitrogen oxides.

The kitchen vent or open window may waste a lot of heat, however. Another solution, though much more expensive, is to install a heat recovery ventilator. The ventilator exchanger pulls fresh air in from the outdoors and exhausts stale indoor air. While this is taking place, warmth from the outgoing indoor air is transferred to the incoming fresh air in a heat exchanger. Heat recovery ventilators are discussed in the DNRC publication, **Ventilating Your Energy-Efficient Home**.

Two prototype gas ranges that produce lower combustion emissions are now being tested. One of these uses a stainless steel double-ring burner insert, forcing the gas flame between the two rings. This reduces emissions of nitrogen oxides, but increases carbon monoxide levels at lower temperatures. A second prototype range uses a jet-powered ceramic infrared burner to reduce emissions and increase efficiency. These burners use both radiant and convective heating to transmit 70-75 percent of the heat available for cooking, compared to 40-45 percent for conventional gas ranges. In newer energy-efficient gas stoves, the pilot light is replaced with an electric ignition. Such devices can save about $15 to $20 per year at today's gas prices, or about $270 over the life of the stove. The electric ignition also cuts down on pollutants produced by the pilot light.

# Gas or Propane Refrigerators

In Montana, gas or propane refrigerators are most often found in isolated locations where electricity is not available, such as remote cabins or ranches. Many are installed in motor homes and other recreational vehicles. Most gas refrigerators run on liquid propane, although some will burn natural gas or even kerosene.

Except for their modest size, gas refrigerators look like modern electric models, and many have small freezer compartments. Most of the gas refrigerators have capacities of less than 10 cubic feet. One 10-cubic foot model uses 142 cubic feet of propane per week. This would cost about the same to operate as electric refrigerators in the same size range.

Gas refrigerators are more expensive than their electric counterparts. Prices range from $800 for small models to $1,100 - $2,000 for 10-cubic foot models. These refrigerators are available through recreational vehicle dealers and LP gas retailers.

# Gas Clothes Dryers

Gas clothes dryers provide another opportunity for using gas efficiently in your household. Unfortunately, gas dryers are not required to carry Energy Guide Labels. There are, however, several energy-saving and convenience features you can look for when purchasing a dryer, such as a moisture sensor control, cool-down cycle, and electronic ignition.

Dampness or moisture sensors will turn the dryer off when clothes are dry, preventing the dryer from running when it's not needed. Some new models with moisture sensors allow you to select the amount of moisture retained in drying clothes, such as "cupboard dry" or "iron dry." A cool-down cycle will also conserve energy, using dryer heat to finish the drying cycle rather than dissipating heat to the surrounding air after the dryer shuts off. Electronic ignition replaces a wasteful pilot light on gas dryers, cutting gas use by about one-third.

When installing a gas clothes dryer, remember that they must be vented outside if located in a habitable area of the house or a room containing other fuel burning appliances.

# IS GAS FOR YOU?

There's no doubt that the new gas furnaces and appliances are dependable and efficient. The cost of gas is lower than most other fuels. Natural gas also burns cleaner than wood or coal, and there is no need to move heavy fuel around.

When it's time to replace an existing gas furnace, the newer, more efficient models may save you money in the long run. An array of heating system options are now available — from new, high efficiency gas furnaces to integrated water heating and space heating systems. A careful comparison of life-time savings for different furnaces will help you make an informed decision.

Until replacements are necessary, the best investment you can make is a regular maintenance schedule for your heating system, maintaining its efficiency and lengthening its life. You may wish to have a contractor do this maintenance or do it yourself. You also might want to consider add-ons to increase the efficiency of your present furnace. When combined with home weatherization, the savings may surprise you.

Other gas appliances such as water heaters also offer opportunities for savings and increased efficiency. Becoming familiar with available options and their advantages and disadvantages will help you make the best selection.

It's your choice — you control how much of your money goes up the chimney, down the drain, or stays in your pocket.

# Other Reading

## FURNACE MAINTENANCE AND RETROFITS

**Do You Really Know Your Furnace's Efficiency?**
Mechanix Illustrated. New York, New York. February 1984.

**Energy-saving Thermostats.**
Consumer Reports. Mount Vernon, New York, October 1985.

**Furnace Gadgets — Hype or Help?**
Roadale's New Shelter. Emmaus, Pennsylvania. February 1985.

**Furnace Maintenance.**
The Family Handyman. St. Paul, Minnesota. February 1986.

**Heating System Add-Ons.**
Popular Science. New York, New York. October 1984.

**Mechanical Systems Retrofit Manual — A Guide for Residential Design.**
Knight, Paul A., New York. Van Nostrand Reinhold Company. 1987.

## HIGH EFFICIENCY FURNACES AND HEATING SYSTEMS

**Buyer's Guide: Efficient Gas Heating Equipment.**
American Gas Association. Arlington, Virginia. Undated.

**Can Heat Pumps Help?**
Consumer Reports. Mount Vernon, New York. October 1985.

**Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment.**
Gas Appliance Manufacturers Association. This directory lists AFUE ratings for furnaces and boilers, based on data submitted by manufacturers and verified by an independent laboratory. See the reference under water heaters for a mailing address.

**Fuel-saving Furnaces.**
Popular Science. New York, New York. October 1985.

**Heat-pipe Furnace.**
Popular Science. New York, New York. February 1984.

**High-efficiency Furnaces.**
Consumer Reports. Mount Vernon, New York. January 1987.

**New Products: Home Energy.**
Popular Science. New York, New York. October 1986.

**Using the Earth to Heat and Cool Homes.**
Montana Department of Natural Resources and Conservation. January 1985.

## WATER HEATERS

**Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment.**

Gas Appliance Manufacturers Association. GAMA's certification program for water heaters covers electric, gas, oil, and heat pump water heaters. It lists manufacturers, hundreds of model selections, energy factors, first-hour ratings, and operating costs. The combined water heater and furnace directory is available for $10 and can be ordered directly from GAMA in Arlington, Virginia (703) 525-9565, or write to GAMA Efficiency Certification Program, ETL Testing Laboratories, Industrial Park, Route 11, Cortland, New York 13045. The directory should help you zero in on the best water heater for your household.

**Endless Hot Water?**

Energy Auditor and Retrofitter. Berkeley, California. January/February 1986.

**How to Stay in Hot Water.**

Consumers' Research. Washington, D.C. April 1985.

**Tankless Water Heaters.**

Consumer Reports. Mount Vernon, New York. January 1986.

**3 New Ways to Heat Water and Proven Ways to Conserve It.**

The Family Handyman. St. Paul, Minnesota. December 1984.

## FURNACE SIZING

The videotape **How to Calculate Design Heat Load**

and an accompanying instructional booklet are available on loan through the Montana Public Library film service. These show how heat-loss calculations are done to properly size a furnace for a new house. Check with your local public library for more information.

**Load Calculation Guide, One and Two Family Dwellings for Heating and Air Conditioning.**

Sheet Metal and Air Conditioning Contractors' National Association, Inc. SMACNA. Vienna, Virginia. 1975.

**The Superinsulated Home Book.**

Nisson, J. E., Ned Nisson, and Guatam Dutt. New York. John Wiley and Sons. 1985.

## FURNACE REPLACEMENT

**When You Should Replace Your Furnace.**

Home Mechanix. Holmes, Pennsylvania. September 1987.

## COSTS

**Energy Answers, Improving Lifestyles, Determining Your Energy Costs.**

Workbench. Kansas City, Missouri. September/October 1985.

## SAFETY

**Fearful of Flue Gases.**
Progressive Builder. Harrisville, Pennsylvania. August 1986.

**Indoor Air Pollution: If You Think Your Home is a Bastion of Clean Air in a Polluted World, Think Again.**
Consumer Reports. Mount Vernon, New York. October 1985.

**Introducing Supplemental Combustion Air to Gas-Fired Home Appliances.**
U.S. Department of Energy. DOE/CE/15095-7. December 1983.

**One and Two Family Dwelling Codes.**
Building Code Officials and Administrators International, Inc. Available from Building Codes Bureau, Montana Department of Commerce. 1983.

**Ventilating Your Energy-Efficient Home.**
Montana Department of Natural Resources and Conservation. October 1987.

## ADDITIONAL INFORMATION SOURCES

**The Montana Energy Book — Proven Ways to Save Money In and Around Your Home.**
Montana Department of Natural Resources and Conservation. June 1986.

**Twelve Ways to Turn Down Your Energy Bills.**
Montana Department of Natural Resources and Conservation. June 1986.

**National Appropriate Technology Assistance Service** (NATAS) is an information and technical assistance source provided by the U.S. Department of Energy. NATAS can answer questions about energy conservation methods and devices, and energy-related appropriate technologies, a term that generally refers to technologies that use the sun, wind, and water resources. Contact it in Butte by calling 1-800-428-1718 (in Montana) or 1-800-428-2525 (in other states). Or write NATAS, P.O. Box 2525, Butte, Montana 59702-2525.

# Appendix

Work sheets in this appendix allow you to compare the annual savings that can be achieved by switching to gas or by replacing your present furnace with a more efficient one. As with any economic analysis, the work sheets look more difficult than they really are.

Work Sheet 1 allows you to calculate the annual heating cost of your present heating system. Obtain from your local utility or fuel supplier the amount of fuel (natural gas, propane, fuel oil, or electricity) you used during the past year and fuel use during a summer month (July or August). You can also obtain the information from past bills if you have them. Select the type of fuel on Work Sheet 1 that you are now using for heating and follow that column. Ignore the other columns.

### Work Sheet 1. Calculate Your Annual Heating Costs

**NATURAL GAS**

| | | EXAMPLE |
|---|---|---|
| 1. Total Annual Use in MCF | | 122.31 MCF |
| 2. Gas Use During July or August (use lowest month)* | | 2 MCF |
| 3. Annual Non-heating Gas Use = **LINE 2 X 12** | | 24 MCF |
| 4. Annual Heat Use = **LINE 1 - LINE 3** | | 98.31 MCF |
| 5. Cost/MCF | | $3.40/MCF |
| 6. Annual Heat Cost **LINE 5 X LINE 4** | | $334.25 |
| 7. Annual Heat Use in MCF **ENTER LINE 4** | | 98.31 MCF |

**LP GAS**

| | |
|---|---|
| 1. Total Annual Use in Gallons | |
| 2. Non-heat Use**<br>Range 120 gal/yr | |
| Dryer 96 gal/yr | |
| Water Heating 500 gal/yr | |
| 3. Total Non-heat **ADD 3 LINES ABOVE** | |
| 4. Annual Heat Use = **LINE 1 - LINE 3** | |
| 5. Cost/Gallon | |
| 6. Annual Heat Cost **LINE 5 X LINE 4** | |
| 7. Annual Heat Use in MCF*** **LINE 4 divided by 10.1** | |

**FUEL OIL**

| | |
|---|---|
| 1. Total Annual Use in Gallons | |
| Skip to Line 4 | |
| 4. Annual Heat Use = **LINE 1** | |
| 5. Cost/Gallon | |
| 6. Annual Heat Cost **LINE 5 X LINE 4** | |
| 7. Annual Heat Use in MCF*** **LINE 4 divided by 6.7** | |

**ELECTRICITY**

| | |
|---|---|
| 1. Total Annual Use in Kilowatt Hour | |
| 2. KWH Use During July or August (Use Lowest Month) | |
| 3. Annual Non-Heating Electricity Use = **LINE 2 X 12** | |
| 4. Annual Heat Use = **LINE 1 - LINE 3** | |
| 5. Cost/KWH | |
| 6. Annual Heat Cost **LINE 5 X LINE 4** | |
| 7. Annual Heat Use in MCF*** **LINE 4 divided by 273** | |

* Pick a normal summer month; not one when you had lots of company or were on an extended vacation.

** Make entries only for those propane (LP-Gas) appliances you now own.

*** Now, calculate the amount of natural gas required to supply the same heat.

Work Sheet 2 allows you to estimate the annual savings you can obtain by switching to a more efficient gas heating system. Obtain from your furnace dealer or heating contractor the AFUE (Annual Fuel Utilization Efficiency) of the new furnace or boiler you are considering. You will also need an estimate of the efficiency of your present furnace. Your local utility may be able to give you an estimate of present efficiency or you may use the tables below. Use these efficiencies to look up the fuel use factor in Table 1.

**NOTE:** The approach used in this work sheet assumes that you are replacing your present heating system with a similar system. If the new system requires ductwork and the old one didn't, you must consider heat loss through the ductwork when determining the efficiency of the new system. If all the new ductwork is located in a heated space, losses will be minimal. However, research in Oregon has shown heat losses through ductwork in unheated crawl spaces can reduce the heating system efficiency an additional 25 to 35 percent. Thus a furnace with an AFUE of 83 percent may have a heating system efficiency of only 48 to 58 percent.

## Work Sheet 2. Estimate Your Annual Fuel Savings

| | | | EXAMPLE |
|---|---|---|---|
| 1. | **ENTER LINE 7 FROM WORK SHEET 1** | ______ | 98.31 MCF |
| 2. | Find Fuel Use Factor from Table 1 | ______ | .80 |
| 3. | Gas Use for New System<br>**LINE 1 X LINE 2** | ______ | 78.65 MCF |
| 4. | Current Price of Natural Gas (Ask the local gas utility for the cost per MCF) | ______ | $3.40/MCF |
| 5. | Annual Cost of Present System<br>**ENTER LINE 6 FROM WORK SHEET 1** | ______ | $334.25 |
| 6. | Annual Cost of New System=<br>**LINE 3 X LINE 4** | ______ | $267.40 |
| 7. | Annual Fuel Savings<br>**LINE 5 - LINE 6** | ______ | $66.85 |

## Table 1. Fuel Use Factor
### New Gas System Under Consideration

| **Present Heating System** | **70% AFUE** | **75% AFUE** | **80% AFUE** | **85% AFUE** | **90% AFUE** | **95% AFUE** |
|---|---|---|---|---|---|---|
| Older Gas Unit Converted from Coal 50% Efficient | .71 | .67 | .63 | .59 | .55 | .53 |
| Older Gas Unit (more than 15 years old and in good shape) 60% Efficient | .86 | .80 | .75 | .71 | .67 | .63 |
| Medium Gas Aged Unit (5-15 years old) with Standing Pilot 65% Efficient | .93 | .87 | .81 | .76 | .72 | .68 |
| Newer Gas Unit With Electric Ignition 70% Efficient | 1.00 | .93 | .88 | .82 | .78 | .74 |
| Electric Heat 100% Efficient | 1.43 | 1.33 | 1.25 | 1.18 | 1.11 | 1.05 |

If you are considering switching to a new heating system, work sheet 3 allows you to compare the expected savings of different systems over their lifetimes. This work sheet evaluates an investment in a new heating system in the same way that you, or a financial planner, would evaluate any other investment. It calculates the value today of the future energy savings (their present value shown below as an S- value), and compares this with the cost of the new heating systems.

To complete work sheet 3, obtain the cost of the new heating system and its installation from a heating contractor. This should include the cost of minor ductwork changes and bringing a new gas line to your house, if necessary.

You will also have to estimate the rate of return (adjusted for inflation) that you would expect on a long-term investment, such as the funds you are setting aside for retirement. If this is not something you usually do, the current interest rate on new mortgages minus the current rate of inflation should be close enough. The current rate of inflation is reported monthly in the newspaper or publications such as the Wall Street Journal or Business Week. Ask your librarian for assistance if you need more help.

## Table 2. Multipliers For Lifetime Savings Calculations

| **Long Term Rate of Return Adjusted for Inflation (Line 4c)** | **Life of Furnace in Years (Line 3)** | | | | | |
|---|---|---|---|---|---|---|
| | **7** | **10** | **15** | **20** | **25** | **30** |
| 1 | 6.8 | 9.5 | 13.9 | 18.1 | 22.1 | 25.9 |
| 2 | 6.5 | 9.1 | 13.0 | 16.5 | 19.7 | 22.6 |
| 3 | 6.3 | 8.6 | 12.1 | 15.0 | 17.6 | 19.8 |
| 4 | 6.1 | 8.2 | 11.3 | 13.8 | 15.8 | 17.5 |
| 5 | 5.9 | 7.9 | 10.6 | 12.6 | 14.3 | 15.5 |
| 6 | 5.7 | 7.5 | 9.9 | 11.6 | 12.9 | 13.9 |
| 7 | 5.5 | 7.2 | 9.3 | 10.8 | 11.8 | 12.5 |
| 8 | 5.4 | 6.9 | 8.7 | 10.0 | 10.8 | 11.4 |
| 9 | 5.2 | 6.6 | 8.2 | 9.3 | 9.9 | 10.4 |
| 10 | 5.0 | 6.3 | 7.8 | 8.6 | 9.2 | 9.5 |

## Work Sheet 3. Compare The Lifetime Savings Of Different Heating Systems

| | | | | | EXAMPLE |
|---|---|---|---|---|---|
| 1. | Annual Fuel Savings<br>**Enter Line 7 from Work Sheet 2** | | ______ | | $66.85 |
| 2. | Cost of new system<br>**Enter bid from contractor** | | ______ | | $965 |
| 3. | Estimated life of new system<br>**Enter contractor's estimate** | | ______ | | 20 yrs |
| 4A. | Current interest rate on new mortgages | ______ | | 11% (0.11) | |
| 4B. | Current inflation rate | ______ | | 4% (0.04) | |
| 4C. | Approximate rate of return (adjusted for inflation) on long-term investment<br>**Line 4A - 4B or your own value** | | ______ | | 7% (.07) |
| 5. | Multiplier from Table 2<br>**Use Lines 3 and 4C to locate multiplier** | | ______ | | 10.8 |
| 6. | S-Value<br>**Line 1 X Line 5** | | ______ | | $721.98 |
| 7. | Net value of system's lifetime savings<br>**Line 6 - Line 2** | | ______ | | – $243.02 |

This approach assumes that fuel prices are increasing at the same rate as inflation. This approach also disregards any differences in maintenance costs between heating systems.

To compare different gas heating systems you are considering, you will have to do the calculations for each system. To determine which is the best buy, rank the results (line 7) from highest to lowest. The heating system with the lowest rank should be the best buy. When line 7 is less than zero, the new system you are considering will not pay for itself. When line 7 is positive, the new system you are considering will save you money over its life. If your furnace has broken down and needs replacing, the system that gives the largest net savings (or smallest negative number if all are negative) is the best value.

Table 3 compares the life cycle costs of several heating systems having different efficiencies and using different fuels. As you can see, the best investment in this example is switching from an electric forced air system to a gas forced air system.

**You need to do the calculations for your own situation to see what combination of efficiency, heating system cost, fuel prices, interest rates and inflation will result in the best investment for you. There are too many variables to suggest a "best" answer for everyone.**

Table 3 values assume a furnace life of 18 years, inflation at 4 percent, and interest on a mortgage at 11 percent. Price of gas assumed to be $3.400 per MCF, electricity $0.056 per kWh, propane $0.669 per gallon, and $0.69 per gallon for oil. Assumes 98.31 MCF yearly gas use or equivalent for heating. A minus value means no savings.

## Table 3. Comparison Of Life Cycle Costs Of Heating Systems

| Type of Heating System | Efficiency | System Cost | Annual Savings | S-value | S-value Minus System Cost | Rank |
|---|---|---|---|---|---|---|
| Old gas furnace | 60% | | | | | |
| New gas furnace | 75% | $ 965 | $ 67 | $ 684 | −$ 281 | 4 |
| Old gas furnace | 60% | | | | | |
| New gas-condensing furnace | 86% | $ 1,900 | $ 101 | $ 1,034 | −$ 866 | 6 |
| Old gas furnace | 60% | | | | | |
| New gas-condensing furnace | 93% | $ 2,500 | $ 119 | $ 1,214 | −$ 1,286 | 7 |
| Old gas furnace | 60% | | | | | |
| New gas-pulse furnace | 97% | $ 3,200 | $ 127 | $ 1,305 | −$ 1,895 | 8 |
| Old oil furnace | 60% | | | | | |
| New gas furnace | 80% | $ 1,265 | $ 206 | $ 2,111 | +$ 846 | 3 |
| Old propane furnace | 60% | | | | | |
| New gas furnace | 80% | $ 1,265 | $ 418 | $ 4,275 | +$ 3,010 | 2 |
| Old electric forced-air | 100% | | | | | |
| New gas furnace | 86% | $ 1,900 | $ 498 | $ 5,096 | +$ 3,196 | 1 |
| Old electric baseboard | 100% | | | | | |
| New gas furnace | 86% | $ 5,500* | $ 498 | $ 5,096 | −$ 404 | 5 |

* This system cost includes ductwork installation.

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